IMPACT OF COOPERATIVE LEARNING STRATEGY ON PROCESS SKILLS ACQUISITION AND PERFORMANCE IN CHEMISTRY AMONG SECONDARY SCHOOL STUDENTS, ZARIA KADUNA STATE, NIGERIA

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY ZARIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER DEGREE IN SCIENCE EDUCATION

DEPARTMENT OF SCIENCE EDUCATION,
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MARCH, 2018

DECLARATION

I hereby declare that the work in this Dissertationentitled “Impact of Cooperative LearningStrategy on Process Skills Acquisition and Performance in Chemistry among Secondary School Students, Zaria Kaduna State, Nigeria” was carried out by me in the Department of Science Education, Ahmadu Bello University, Zaria. The information derived from the literature has been appropriately acknowledged in the text by means of APA style of references. No part of this thesis has been presented wholly or partly for the award of a higher degree at this or any other Institution.

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Ismaila AHMAD Date
MED/EDUC/12422/2011-2012
P15EDSC8087

CERTIFICATION

This Dissertationentitled "Impact of Cooperative Learning Strategy on Process Skills Acquisition and Performance in Chemistry among Secondary School Students, Zaria Kaduna State, Nigeria" by Ismaila AHMAD (M.ED/EDUC/12422/2011-2012/P15EDSC8087) meets the regulation governing the award of Masters Degree in Science Education of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my parents Malam Ahmad Ibrahim and Malama Maryam Muhammad Sani, My step-mothers Malama Ruqayya Sulaiman and late Malama Hafsa Abdullahi, my scholars, members of my immediate family, my wife Sa'adatu Abdullahi, my children Abdullahi Ismail and Juwairiyya Ismail. I love you all.

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In the name of Allah the most gracious the most merciful, we thank him and we seek for his assistance and forgiveness, we seek for his refuge from the evils of our souls and our actions. Whosoever is guided by Allah no one can misguide him and whomsoever is misguided no one can guide him. May the peace and blessings of Allah be upon his noble prophet (SAW).

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ABBREVIATIONS USED

CLS	–	Cooperative Learning Strategy
SPS	–	Science Process Skills
CPT	–	Chemistry Performance Test
TOSPS	–	Test of Science Process Skills
AAAS	–	American Association for the Advancement of Science
WAEC	–	West African Examinations Council
SSCE	–	Senior Secondary Certificate Examinations
STAN	–	Science Teachers Association of Nigeria
MAN	–	Mathematics Association of Nigeria
NERDC	–	National Education Research and Development Council
EXG	–	Expert Group
SPSAT	–	Science Process Skills Acquisition Test
TOPS	–	Test of Practical Skills

OPERATIONAL DEFINITION OF TERMS

Cooperative Learning Strategy: is an instructional strategy where students of small groups in a learning situation work together to achieve a common task.

Jigsaw Model: is a cooperative learning model applicable to team assignments that call for expertise in several distinct areas where the experts have the responsibility of transmitting their expertise to their teammates under specialized guidance of the teacher.

Science Process Skills: are manipulative skills or methods which are used by science teachers and students to construct new knowledge. When scientists conduct investigations, they use SPS to discover scientific knowledge, which is explained as describing, predicting, explaining, and adapting to phenomena of the natural world.

Basic Science Process Skills: are the processes skills needed for construction of new knowledge and solving problems. They are vital for science learning and concept formation at the Primary and Junior Secondary levels. Examples observation, classification, measurement and so on.

Integrated Science Process Skills: are the processes skills that require more advanced knowledge base. They are more appropriate at secondary and tertiary school levels for the formation of models, experimenting and inferencing. Examples hypothesizing, formation of mental models, interpretation of data among others.

Process Skills Acquisition: is the outcome of students' competency in utilizing their knowledgeof science process skills to solve problems.

Academic Performance: this is the outcome of the test given to the students by the researcher after receiving treatment in chemistry. The aim is to determine the effect of the treatment given to the students.

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ABSTRACT

This study investigated the impact of cooperative learning strategy on process skills acquisition and performance in chemistry among secondary school students, Zaria Kaduna State, Nigeria.The population of the study comprised of 1743 SS II science students in Zaria Education zone. Non - random sampling was used to get the sample for the study. The sample of the study comprised of 162 students out of which 93 were males and 69 were females; non – random sampling technique was used to get the sample. Quasi – experimental pretest posttest control group design was adopted for the study. The experimental group was exposed to cooperative learning strategy and the control group was exposed to lecture method. Two instruments; Test of Science Process Skills (TOSPS) with reliability coefficient of 0.79 and Chemistry Performance Test (CPT) with reliability coefficient of 0.88, were used to collect the data used for the study. Four research questions with their corresponding hypotheses were raised and tested at $p \leq 0.05$ level of significance. The data collected were analysed using t - test statistics. Major findings from the study were: Chemistry students taught using cooperative learning strategy performed significantly better in their acquisition of science process skills than those taught using lecture method, Chemistry students taught using cooperative learning strategy performed significantly better in performance test than those taught using lecture method. Cooperative Learning Strategy (CLS)was not gender sensitive to academic performance and acquisition of science process skills. Based on the findings, it is recommended that,Special Training Programme should be organized for Chemistry Teachers of Secondary Schoolson the use of Cooperative Learning Strategy in the teaching and learning of chemistry so as to enhance general performance of students.

CHAPTER ONE

THE PROBLEM

1.1 Introduction

Chemistry is a science discipline that deals with the study of composition, properties and uses of matter. It describes how one or two substances interact with one another to give rise to different substances (Ahmad, 2010). According to Wu and Foos (2010) Chemistry is a fundamental discipline that accounts for life at the molecular level. Chemistry is a subject of universal interest in human development with regards to the utility of its knowledge in real-life situations likely to be faced by many of the students someday. Chemistry has virtually permeated most aspects of our economic and/or public life (Wu & Foos; 2010). Chemistry embraces a variety of fields of study and is combined with other subjects to satisfy the Senior Secondary School Examination (S.S.C.E) requirements. Its lively inter-disciplinary nature seems to reflect an exciting appeal to a wide audience as a focus for examining functional concepts of normal life and systems of health and welfare provisions (Jegede, 2012).

It was opined by Wu and Foos (2010) that the most exciting prospect of schooling is the harmonious development of individual’s potentials coupled with coherent preparation for happy and useful living in the society. On this basis, the effective instruction and application of chemical principles in real life situations can improve the quality of human life and preserve the environment. In spite of the importance of chemistry as enumerated above, observation of students’ performance in chemistry in the Secondary School Certificate Examination (S.S.C.E) reveal that only a very negligible number of students perform well in the examinations (Jegede, 2012; Muhammad, 2014). A study conducted by Ahmad (2010), indicated that, inability of teachers and students to adopt different ways of learning and lack of exposure to current materials and resources for the learning processes are some of the challenges faced by chemistry teachers and students. These challenges are some contributors to the poor academic performance of students in SSCE examinations.

Academic performance is simply the attainment of a set of objectives in a given instruction. Academic performance is the measure of the general outcomes at the end of instruction. In science instruction for instance, if a learner accomplishes a task successfully and attains the specified goals for a particular learning experience, he is said to have performed academically good (Igboegwu & Egbutu, 2011). Students' scores in science subjects for sometimes have been below expectation (Aderogba & Aanu, 2011).

For quite sometimes, a number of teaching methods/strategies (such as lecture, discussion, discovery etc) have been employed in the teaching of chemistry but performance in SSCE chemistry continued to be poor. This continuous trend in the performance of students in Science subjects such as chemistry is alarming that such methods used in teaching/ learning chemistry appear not to be effective. Ameh and Dantani (2012), criticized the lecture method used by teachers because only hardworking students can benefit from it. It encourages rote-learning instead of meaningful learning. Bichi, (2002) and Usman (2000;2007) have separately observed that lecture method encourages rote-learning without aiding understanding, thereby resulting in poor performance (Zakaria, Solfitris, Daud & Zainal Abidin, 2013). It is therefore very imperative to employ the use of different strategies that could improve the performance of students in chemistry in school examinations. Some of the strategies that could be usedare use of analogy, cooperative learning, problem solving, conceptual change and other effective teaching strategies. Current trend will require strategy that will allow students to interact, exchange ideas and acquire knowledge and skills in understanding and problem solving in chemistry. This may be achieved through the use of cooperative learning strategy.

Cooperative learning strategy is a strategy in which small teams, each with students of different levels of ability use a variety of activities work together to improve their understanding of a subject. Each member of a team is expected not only to learn what is being taught but also to help team mates learn, thus creating an atmosphere of achievement. Research reveals that students completing cooperative learning group's task tend to have higher academic test scores, higher self-esteem and greater comprehension of the content and skills they are studying (Olorukooba, 2006; Norah, 2015). In a cooperative learning classroom, students work together to attain group goals that cannot be obtained by working alone. In this classroom structure, students discuss the subject matter, help one another learn, and provide encouragement for members of the group (Olatoye, Aderogba & Aanu, 2011). Several studies conducted by Yusuf, (2005); Olorukooba, (2006); Igboegwu & Egbutu, (2011) have reported that cooperative learning strategy promotes significant academic achievement of students in science, social valuable skills, critical thinking skills and science process skills.

Process skills are avenues that scientists utilize in arriving at scientific knowledge (Green & Ihenko, 2006). Science process skills include skills that every individual could use in each step of his/her daily life by being scientifically literate and increasing the quality and standard of life by comprehending the nature of science. Therefore, these skills affect the personal, social and global life of an individual (Ozgelen, 2012). Science Process Skills (S.P.S) are the thinking skills that Scientists use to construct knowledge in order to solve problems and formulate results. The scientific method, scientific thinking , and critical thinking are also terms that have been used to describe these skills, but last two decades, the phrase " science process skills" has become more common (Ozgelen, 2012). When scientists conduct investigations, they use SPS to discover scientific knowledge, which is explained as describing, predicting, explaining, and adapting to phenomena of the natural world (Carin, Bass & Conant, 2005).

Science Process Skills have been described as mental and physical abilities, competencies which serve as tools needed for effective study of science and technology as well as problem solving, individual and societal development (Igboegwu & Egbutu,2011)). The American Association for the Advancement of Science (AAAS) classified the science processes skills into fifteen (Usman & Ibrahim, 2012). These are: observing, measuring, classifying, communicating, predicting, inferring, using number, using space/time relationship, questioning, controlling variables, hypothesizing, operational definition, formulating models, designing experiment and interpreting data. Akinbobola and Afolabi, 2010, viewed that Science Process Skills can be classified into two categories; basic science process skills and integrated science process skills. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. Basic science processes are vital for science learning and concept formation at the primary and junior secondary school levels. More difficult and integrated science process skills are more appropriate at the secondary and tertiary school levels for the formation of models, experimenting and inferencing. Hence both basic and integrated science process skills are relevant and appropriate at the senior secondary schools in Nigeria (Akinbobola & Afolabi, 2010).

According to (Ibrahim & Usman, 2012), the basic science process skills comprised of observing, measuring, classifying, communicating, inferring, using number, using space/time relationship and questioning while integrated science process skills are controlling and manipulating variables, hypothesizing, defining operationally, formulating models, designing experiment and interpreting data.

It was opined by Ozgelen (2012), that the basic SPS consist of observing, using space/time relationships, inferring, measuring, communicating, classifying and predicted. Integrated SPS include controlling variables, defining operationally, formulating hypothesis, interpreting data, experimenting, formulating models and presenting information. The basic SPS is an essential tool needed by scientist to construct new knowledge and solve problems. While the integrated SPS requires a more advanced knowledge base. For instance, identifying and controlling variables is an essential skill for successfully managing scientific investigation (Ozgelen, 2012). Studies have indicated that students exhibit very poor science process skill acquisition (Igboegwu, 2006 & Nwosu, 2006). This poor skill acquisition has been attributed to a number of factors such as teacher variable that is the teacher's method of teaching. Njelita (2007) found out that innovative teaching strategies such as inquiry, problem solving, cooperative, demonstration methods are better than the conventional method in acquisition of Science Process Skills and also not gender sensitive

The concept "gender" refers to the amount of masculinity or femininity found in an individual. The influence of gender on students' performance has a long time been a concern to many educational researchers. But surprisingly no consistent results have been obtained (Muhammad, 2008). Gender is a major factor that influences career choice and subject interest of students. Okeke (2008) described the male attributes as bold, aggressive, tactful, economical use of words while the females are fearful, timid, gentle, dull, submissive and talkative.May be that is why Ezeudu and Theresa (2013), stated more difficulty works are usually reserved for males while the females are considered famine in a natural setting. Thus in schools males are more likely to take difficult subject areas like science (chemistry) while the females take to career that will not conflict with marriage chances, marriage responsibilities and motherhood (Okeke, 2008). Bandele

(2000), believed that males perform better than girls in science education programs. Contrary to this, Ogunboyede (2003)opined that boys are not better than girls in terms of educational performance. It was found by Philips (2006) that girls excel consistently in arithmetic computation and are superior in reading and hand writing while boys are slightly better in arithmetic reasoning, history, geography and geometry.Bichi (2006), reported that many studies in Singapore suggested that boys achieve better than girls in mathematics, while Lorchugh (2006), did not find either gender performing better. Other researchers believed that, if boys and girls are given equal opportunities, they will perform equally well (Usman, 2010).

It is the focus of this study to investigate the impact of cooperative learning strategy on science process skills acquisition and academic performance among secondary schools chemistry students in Kaduna state. It is also the focus of this study to investigate the difference in science process skills acquisition and academic performance among males and females secondary schools chemistry students in Zaria, Kaduna state, Nigeria.

1.1.1 Theoretical Framework

This study is based on Constructivist and Motivational theory of learning. The term Constructivism refers to the idea that learners construct knowledge for themselves; each learner individually (and socially) constructs meaning as he or she learns (Richard, 2004). Learning is an active process in which the learner uses sensory input and constructs meaning out of the world. The crucial action of constructing meaning is mental: it happens in the mind. Physical actions, hands-on experience may be necessary for learning, especially for children, but it is not sufficient; we need to provide activities which engage the mind as well as the hands (Mayer; Richard, 2004). In their opinion, Eggen, Jacobsen, & Kauchak (2006) opined that the constructivist learning environment prioritises and facilitates the students' active role. The shift towards students becoming more active learners they contend is due to the belief that learners are naturally curious. In the context of this study, this theory emphasises the need for students to be allowed to be actively involved in the learning process rather than being solely passive learners. To do this effectively students must have hands on experience where they are allowed and encouraged to critically explore their learning environment.

According to constructivism, learning occurs by an active construction of a meaning by learners rather than learners being passive recipient of information (Vygotsky, 1987). His works suggests that knowledge is first constructed in a social context and is then appreciated by individuals. Constructivism, applied as an explanatory framework of learning, describes how the learner constructs knowledge from experience, which makes it unique to each individual (Richard, 2004). The theory of constructivism emphasizes on the role of active involvement in learning in relation to child's environment. Constructivism affirmed that, learning is based on the belief that knowledge can be constructed by learners themselves, if they are properly guided through active mental process of development. In cooperative learning, students interact in group work to discover facts and construct knowledge through the guidance of the teacher.

The motivational theory stresses students' incentives towards academic work. According to Olorukooba, (2001) the motivational theory of cooperative learning emphasizes the reward structures; the cooperative goal structure, the competitive goal structure and the individualistic goal structure. According to research, students learn better when they are challenged and can be motivated by their classmates. For example, Dallmer (2007) noted that when a student arrived at a clear conclusion to a problem which had caused frustration in the class, his classmates would perceive the solution and the problem as being less difficult, because it was solved by a fellow student. Students often believe that teachers are experts in the subjects that they teach, so in a traditional, teacher-centered classroom, students may be intimidated by the subject matter, thinking that it is only easy or solvable by the teacher or another expert. A potential result of this perception is that when students try to work on the material by themselves, they can become very frustrated or lack motivation to complete the task (Chih-Hsiang, Gwo-Jen, Fan-Ray & Iwen, 2013). It was opined by Robyn (2014), that in a cooperative learning environment the students are involved in deriving solutions to the questions through group participation; whereby the students get to integrate different methods and processes of solving the same "question" especially from their colleagues and teachers. When students solve the same problems especially through group work, there would be differences among the students who work independently when handling assignment problems. The differences in level of understanding among students who learn through cooperative interaction, and their counterparts who learned via the teacher-centered approach, can be compared when the two teams are evaluated afterwards.

In relation to learning and its social nature, (Siegel,2005) notes that students appear to think in conjunction or partnershipwith others and with the help of culturally provided tools and implements. However, according to (Yamarik, 2007; Anthony, 2013), for learning to occur, students must interact with each other and the instructor in order to arrive at shared meaning and to make sense of what they are learning. Interpersonal interaction provides the social context for the mutual construction of understanding and has been demonstrated to play a major role in the learning process.This social context of learning is crucial for motivation, critical judgment and problem solving. Skills and experiences, which are the parts of components of knowledge, are obtained through social interaction.

However, Johnson & Johnson, (1999) argued that the motivational concern of cooperative learning boarders around individuals observing someone else getting reinforced for a particular behavior. According to (Davidson & Major, 2014; Norah, 2015) cooperative learning as a motivational strategy works where some students like to cooperate with their peers. Teachers, in an effort to meet their students' needs for affiliation, autonomy, and physical activity, have utilized cooperative learning to address the students' need to be social. The levels of students' motivation, whether to succeed individually or in a group increases with the use of cooperative learning strategies. They maintained that, once motivated, students interact with each other and with the learning material in the way that supersedes students in a traditional, teacher-centered classroom. Given the nature of the student and the reportedly positive results of cooperative learning strategies on cognitive and affective domains, it would appear that cooperative learning is an essential element in instruction.

Since in cooperative learning environment, the teacher always supports and encourages the learners to take part in the learning process, the students get encouraged by the teacher for their contribution in carrying out the group task. It is therefore hoped that students may also display such behavior of participating and contributing to the group activity so that they can learn and construct meaning of the concepts they have learnt. This study adopts the JIGSAW I model of cooperative learning of Elliot (1978) to determine its effects on science process skills acquisition and academic performance among secondary schools chemistry students in Kaduna state.

1.2 Statement of the Problem

Many researchers have described chemistry to be an abstract and difficult subject to learn by students. Chemistry is one of the physical sciences that is affected by high underachievement by learners (Abuzer, 2009). The performance of students in science reflects how well they understand science concepts and is a reflection of how good the instruction is (Muhammad, 2014).The West African Examinations Council (WAEC) chemistry results for students in Kaduna State is presented in Table 1.1. The results appear to be significantly fluctuating. This shows that students' performance in chemistry is not good and stable.

Table 1.1: Kaduna State Students Performance in Chemistry at WAEC

Year	No of Candidates Registered	PASS at Credit Level (%)	Rate of Failure (%)
2010	43223	43.42	56.58
2011	42851	18.50	81.50
2012	47823	19.00	81.00
2013	47757	25.61	74.39
2014	57575	23.89	76.11
2015	64162	34.76	65.24

Source: WAEC Chief Examiners' Reports (2010 – 2015).

In spite of the importance of chemistry, observation of students' performance in chemistry in the Secondary School Certificate Examination (SSCE) revealed that only a very negligible number of students performed well in the examinations. The poor performance of students in chemistry has continued to be a major cause of concern to all, particularly those in the mainstream of chemical education in Nigeria. A number of factors have been attributed to be responsible for the poor performance of Nigerian students in chemistry. A study conducted by Ahmad (2010), indicated that, inability of teachers and students to adopt different ways of learning and lack of exposure to current materials and resources for the learning processes are some of the challenges being faced by chemistry teachers and students. Other factors have been attributed by Adesoji (2008) to be poor methods of instruction, teacher attitude, laboratory inadequacy, poor science background and non-availability of effective teaching and learning resources in classrooms. Several researchers (Jegede, 2012 & Muhammad, 2014) have continued to look for better ways of teaching chemistry as one of the basic branches of science. Studies have indicated that students exhibit very poor science process skill acquisition (Igboegwu, 2006 & Nwosu, 2006). This poor skill acquisition has been attributed to a number of factors such as teacher variable that is the teacher's method of teaching. Njelita (2007) found out that innovative teaching strategies such as inquiry, problem solving, cooperative, demonstration methods are better than the conventional method in acquisition of Science Process Skills.The problem of this study therefore was to investigate the impact of cooperative learning strategy on science process skills acquisition and academic performance in chemistry among Senior Secondary School Students in Kaduna State.

1.3 Objectives of the Study

The main objective of this study was to investigate the impact of cooperative learning strategy on science process skills acquisition and academic performance in chemistry among Senior Secondary School Students in Kaduna State. While the specific objectives of this study are to:

1. investigate the effect of cooperative learning strategy on Science Process Skills acquisition among SS II Chemistry students.
2. determine the effect of cooperative learning strategy on Performance of SS II chemistry students.
3. investigate the effect of cooperative learning strategy on Science Process Skills acquisition among male and female SSII chemistry students.
4. determine the effect of cooperative learning strategy on Performance of male and female SS II students in chemistry.

1.4 Research Questions

The following research questions were formulated for answering.

1. What would be the difference in science process skills acquisition between SS II chemistry students taught using cooperative learning strategy and those taught with lecture method?
2. What is the difference between the academic performance mean scores of SS II chemistry students taught using cooperative learning strategy and those taught using lecture method?
3. What would be the difference in science process skills acquisition among SS II male and female chemistry students taught using cooperative learning strategy?
4. What would be the difference in academic Performance mean scores of SS II male and female chemistry students taught using cooperative learning strategy?

1.5 Null Hypotheses

The following research hypotheses were formulated for testing at $p \leq 0.05$significant levels

H_{O1}: There is no significant difference in science process skills acquisition between SS II chemistry students taught using cooperative learning strategy and those taught using lecture method

H_{O2}: There is no significant difference between the academic performances mean scores of SS II chemistry students taught using cooperative learning strategy and those taught using lecture method

H_{O3}: There is no significant difference in science process skills acquisition between male and female SS II chemistry students exposed to cooperative learning strategy

H_{O4}: There is no significant difference between the academic performance mean scores of male and female SS II chemistry students exposed to cooperative learning strategy

1.6 Significance of the Study

It is hoped that, the results of this study would hopefully uplift the standard of science education in the following ways.

1. **Improving Students' performances:** Through the acquisition of Science Process Skills (SPS), students' academic performance will be improved in the understanding and appreciating the ways and processes of carrying out scientific investigations. The researcher hoped that, when the process of learning science is given consideration rather than the subject matter; through cooperative learning strategy, performance of the students in chemistry will be improved.
2. **Solving Problems by Students:** The basic value of SPS is allowing students to construct new knowledge that can be used in solving daily problems. When students acquire SPS, they will apply the skills in solving their daily problems
3. **Chemistry Teachers:** Chemistry teachers at SS class may find the result of this study useful in enhancing the method of teaching chemistry through the use of cooperative learning strategy.
4. **Text Book Publishers:** Text book publishers may find the result of this study useful to design activities for teachers and students to perform periodically in order to get constructive ideas through the use of CLS and develop some special skills for problem solving
5. **Curriculum Planners:** Curriculum planners may find the result of this study useful in planning and/or reviewing the science curriculum in such a way that

CLS can be used to improve the level of acquiring SPS among senior chemistry students and promote academic excellence

6. **Professional Bodies:** Professional bodies such as the Science Teachers Association of Nigeria (STAN) and Mathematics Association of Nigeria (MAN) may benefit from this study in organizing seminars, workshops and conferences on the impact of CLS on SPS as well as teaching science and mathematics education.

7. **Educational Agencies:** Educational agencies such as the National Educational Research and Development Council (NERDC) may utilize the outcome of this study to formulate some policies that will promote the use of CLS and encourage group work

8. **Researchers:** The findings of this study serves as a foundation for researchers who may develop interest to carry out further investigations on the impact of CLS on the acquisition of SPS and academic achievement of senior chemistry students. And also the study will add new information to the existing literature in basic science education which other researchers can refer to.

1.7 Scope of the Study

The subjects that were used in this study were SS II Chemistry students. This was because they have some basic knowledge about chemistry. SS I Science students were newly introduced to chemistry, and SS III Science students were preparing for Senior School Certificate Examination (SSCE). Therefore SS II Science students were the most suitable for this study. The subjects were drawn from public senior secondary schools in Zaria Education Zone consisting of mixed and single schools so as to address the issue of poor performance in chemistry among students in public schools. Zaria Education Zone was chosen because it is an academic environment where numerous secondary schools exist, comprising students from different locations in Nigeria. Chemical equilibrium and reversible reactions was used for the study. The topics were chosen because they have been identified to be difficult and contributing to students' poor performances and they are parts of the topics being covered in SS II classes (Doymus, 2007; Gongden, Gongden & Lohdip, 2011; Emmanuel, 2013). Jigsaw I model (Elliot, 1978) of cooperative learning strategy was used for the study. The Jigsaw I was used because it was suitable for teaching the concept that was taught and it requires less time and materials to be applied compared to other forms of Jigsaw. The basic and integrated science process skills (observation, measuring, inferring, interpreting and hypothesizing) were selected. These process skills have been selected because they are relevant to the students' daily activities. Chemistry Performance Test (CPT) made of up fourty (40) multiple choice questions and Test of Science Process Skills (TOSPS) made of up twenty five (25) multiple choice questions were the instruments used for this study.

1.8 Basic Assumptions

The study was based on the following assumptions:

1. that the impact of cooperative learning strategy is measurable.

2. that the acquisition of science process skills can be assessed

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

This study investigated the impact of cooperative learning strategy on science process skills acquisition and performance in chemistry among secondary school students in Kaduna State. This chapter outlines previous studies that have direct relevance to this study. It also highlights some theories which could guide Science teachers to select appropriate strategies for teaching chemistry. The chapter is organized under the following sub-headings.

2.2 Teaching of Chemistry at Secondary Schools

2.3 Science Teaching Methods

2.3.1 Lecture Method

2.4 Concept of Cooperative Learning Strategy (CLS)

2.4.1 Models of Cooperative Learning Strategy

2.4.2 Studies on CLS and Academic Performance in Science

2.5 Science Process Skills Acquisition (SPSs)

2.5.1 Studies on SPSs and Academic Performance in Science

2.6 Gender and Academic Performance in Science

2.7 Overview of Similar Studies

2.8 Implications of the Literature Reviewed for the Present Study

2.2 Teaching of Chemistry at Secondary School Level

Chemistry is a Science discipline that deals with the study of composition, properties and uses of matter. It describes how one or two substances interact with one another to give rise to different substances (Jegede, 2003 & Ahmad, 2010). According to Wu and Foos (2012) chemistry is a fundamental discipline that accounts life at the molecular level. Chemistry is a subject of universal interest in human development regards to the utility of its knowledge in real-life situations likely to be faced by many of the students someday. Chemistry has virtually permeated most aspects of our economic and/or public life (Jegede,2012; Wu & Foos; 2012). Chemistry embraces a variety of fields of study and is combined with other subjects to satisfy the Senior Secondary School Examinations (S.S.C.E) requirements. This could have brought about the importance of chemistry in the secondary school science curricular. Its lively interdisciplinary nature seems to reflect an exciting appeal to a wide audience as a focus for examining functional concept of normal life and systems of health and welfare provisions (Wu & Foos, 2012; Jegede, 2012).

It was opined by Jegede (2012) that the most exciting prospect of schooling is the harmonious development of individuals' potentials coupled with coherent preparation for happy and useful living in the society. On this, the effective instruction and application of chemical principles in real life situations can improve the quality of human life and preserve the environment. In spite of the importance of chemistry as enumerated above, observation on students' performance in chemistry in the Secondary School Certificates Examination (both WAEC and NECO) reveal that only a very negligible number of students perform well in the examinations (Jegede,2012;Muhammad, 2014). A study conducted by Ahmad (2010), indicated that, inability of teachers and students to adapt different ways of learning and lack of exposure to current materials and resources for the learning processes are some of the challenges being faced by chemistry teachers and students.

Reports from WAEC Chief Examiners (2008 - 2013), revealed that candidates' responses to examination questions have not been encouraging. It depicts lack of acquisition of required skills which may stem from inadequate exposure of learners to the use of laboratory apparatus. It is an indication that something is still wrong in Secondary School Chemistry which calls for investigation and remediation (Odum, Akomaye & Chinyere, 2013).

The continuous records of students' poor performance has attracted a lot of assertions (Nwagbo, 2002 & Njoku,2005). Nwosu, (2003) had pointed out that the teacher is an important determinant of the quantity of learning by the learner. Eze and Njoku(2011) opined that teachers are the pivot of the education system and therefore they are at the centre of any reform effort in the system. According to Ikeobi (2010), it is the teacher who organizes the interactions between the subject (learner) and the object (learning materials). It is the teacher who ensures that equipment and materials are properly used by the learner to achieve the expected objectives. All these point to the fact that the teacher is a very significant factor when the learners failed to exhibit the expected mastery in a Science subject like chemistry. The root cause of low performance by students is traced to the approaches and pedagogies employed to deliver the course content. Some teachers consistently use the note they made when they left school for several years without updating their knowledge. These are some of the reasons for poor performance of our students in examinations particularly Chemistry that is deemed abstract and difficult (Nbina, 2012; Muhammad, 2014).

2.3 Science Teaching Methods

Teaching involves helping learners to learn. Learning can be considered as any response to stimuli that leads to residual change in behavior. Learners learn when they interact with resources in their environment that results in change of behaviour. In this regard teachers are therefore concerned with changing. To foster learning teachers decide, usually ahead of time, how they will teach a given objective, for example a concept, a skill or an attitude (Muzumara, 2007& Muhammad, 2014). This signifies that, sorting and understanding methods/strategies by teachers to use and teach a give objective is inevitable.

According to Ashafa and Macheal (2007), a teaching method can be seen as the types of activities pursued by teachers and pupils/students together in group work, surveys, demonstrations, film and TV viewing and so on, which are intended to help pupils/students achieve stated lesson objectives or learning outcomes. Some of the methods used in teaching and learning science include; lecture method, discussion method, demonstration method, discovery method, project method and so on. Most of these methods used in science teaching in secondary schools in Nigeria have been described as inappropriate and uninspiring. Studies (Ibe, 2004; Madu, 2004 & Shaleigh, 2004) have separately pointed out that because of the shortfalls of Science teaching in Nigerian secondary schools because of the methods being used for the instruction (Igboegwu,2012). Nnaobi (2007) and Igboegwu,(2012) asserted that there is no best method of teaching but that effective scientific teaching should be laboratory-centered and activity oriented rather than textbook or lecture-dominated methods which seem to characterize the Nigerian schools.

Effective teaching and learning in any subject at any institution are dependent on the individual strategies used and other variables (Muhammad, 2008). Muzumara (2007) pointed that, there are a number of factors that determine what strategy a teacher should use to accomplish a given learning outcome. These factors may include age level of pupils, amount of time available, type of weather, availability of teaching/ learning resources and the topic being delivered. The choice of the type of strategy to be used for a particular lesson or topic is entirely up to the teacher and he/she feels appropriate for that topic. These being the case it is not usual to see teachers teaching the same topic using different strategies and even if the strategy may be the same the way it is used will differ from teacher to teacher and from class to class. What is important is for the teacher to know and understand his/her Students. Muhammad, (2008) noted that instructional strategy is a major responsible for the level of performance in any subject by the students. Learning difficulties can be solved to a great extent by using appropriate teaching methods.

Teaching methods/strategies may be classified in different ways; those in which the teacher has direct control are referred to as ‘teacher-centred’. These include lecture method, teacher demonstration and teacher questioning. Strategies in which pupils are actively involved are referred to as ‘pupil-centred’. They include laboratory activities, panel discussions, quizzes, and pupils’ project. Teacher-centred keeps learners passive and do not benefit most while pupils-centred allows learners to be actively involved in learning and generate meaningful ideas/ experiences. The other classification of teaching strategies in science is through the presentation of learning outcomes. A teacher may provide experiences in which pupils have to organize different facts to arrive at general principle. This is an inductive approach. In other case, the teacher chooses to introduce a generalization and demonstrate how a given set of known facts fit this generalization. This is deductive approach. Both the teacher-centred and pupil-centred strategies fit well in the two approaches and all depends on who is more active in a given lesson

(Muzumara, 2007). Teacher usually utilizes a variety of teaching methods in one lesson for them to successfully accomplish their tasks. Students can acquire different skills and experiences when allowed to interact among themselves and exchange ideas. Several methods could be used to teach chemistry which perhaps can provide skills and experiences. These methods include laboratory methods, group learning, discovery method, students-led seminars, programmed instruction among others.

2.3.1Lecture Method

Lecture method otherwise called “the chalk board or talk-chalk, “ expository, conventional or traditional method” is described as a method whereby the teacher gives out all the facts he wants his learners to know and master, caring very little whether or not the learners are actively participating in and contributing to the success of the lesson. In this method teacher does most of the talking hence it is regarded as teacher-centred method. It is a verbal presentation of subject matter content, formally organized and supported by others learning media, extending over a protected period of time (Ashafa & Micheal, 2007). According to Muzumara (2007) lecture method is the most commonly used by science teachers despite the fact that it is the most ineffective method of teaching. Whenever the teacher does most of the talking lecture can be said to be taking place. A lecture method is not usually suitable at lower level of education, such as in primary or secondary school. This is because there is limited teacher-pupil interaction, which is necessary for learning to take place. In a lecture communication is basically a one-way channel with very little teacher-students interactions, students simply listen or pretend to listen and write down notes for them to go and study after the lesson.

Students need to be helped to learn and this can best be achieved if the teacher understands his/her students so that she/he can adopt the contents pace and the teaching strategy to be used to meet the needs. A lecture does not allow the teacher to understand his/her pupil since the method does not encourage pupils' activities that can help the teacher know the capability strengths and weakness of the students. A lecture method is also not suitable for the slow learners in class and those students who have the language difficulties. It is usually fast and does not attend to the needs of slow learners and those with language problems. The lecture method is useful where there are large classes and the teachers are few but the material needs to be covered within a short time. The other instances where a lecture may be used are those that would require explanation of scientific concepts, theories or operations of certain equipment that pupils are not familiar with. Muzumara (2007) maintained that, in situation where lecturing cannot be avoided it is necessary to take measures that would increase communication channels between the teacher and pupils and among students themselves in a lesson.

Okoli (2006); Olorukooba, Lawal and Jiya (2012), indicated that an overwhelming majority of science teachers prefer the lecture method of teaching and therefore shy away from innovative activity-oriented teaching methods. On students' academic performance, Bichi (2002) and Usman (2008) have separately observed that lecture method encourages rote-learning without aiding understanding, thereby resulting in poor performance. In an attempt to ensure result oriented chemistry teaching in school, several activity-oriented as well as student-centred strategies has been suggested by different researchers. These strategies include cooperative learning, use of analogy, problem solving, and guided inquiry as well as the use of science process skills. The objective of this study therefore is to investigate the effects of CLS on the AA and SPSs in chemistry.

2.4 Concept of Cooperative Learning Strategy (CLS)

Cooperative learning strategy is a teaching strategy in which small teams, each with students of different levels of ability use a variety of learning activities to improve their understanding of a subject. Each member of a team is expected not only to learn what is taught but also to help teammates learn, thus creating an atmosphere of achievement. Research indicated that students completing cooperative learning groups task tend to have higher academic test scores, higher self-esteem and greater comprehension of the content and skills they are studying (Johnson & Johnson, 1989). In a cooperative learning classroom structure, students discuss the subject matter, help one another learn and provide encouragement for members of the group (Johnson, Johnson & Holubec, 1986). Cooperative learning is an approach to group work that minimizes the occurrence of those unpleasant situations and maximizes the learning and satisfaction that result from working on a high-performance team.

A large and rapidly growing body of research confirms the effectiveness of cooperative learning in education. Cooperatively taught students, unlike students taught traditionally, tend to exhibit higher academic achievement, greater persistence through graduation, better high- level reasoning and critical thinking skills, deeper understanding of learned materials, greater time on task and less disruptive behavior in class, lower levels of anxiety and stress, greater intrinsic motivation to learn and achieve, greater ability to view situations from others' perspectives, more positive and supportive relationships with peers, more positive attitudes toward subject areas, and higher self-esteem (Johnson, Johnson & Stanne, 2006; Feldert & Brent, 2007, Ajaja & Eravwoke, 2010). According to Siegel (2005; Tsay & Brady, 2010) Cooperative is a set of processes that people interact in order to accomplish a specific goal or develop a product, which is usually content specific. Davidson and Major, (2014) describes cooperative learning as a small group of learners who work together as a team to solve a problem, complete a task or accomplish a common goal. When students are in cooperative learning environment in which concepts and ideas are emphasized, it is believed that students are encouraged to contribute their own experiences to the learning activities which connect Science to the real world of students, and help them make connections between classroom learning and new scientific information after they leave the classroom.

Several proponents of cooperative learning as well as other similar researchers stressed that cooperative learning strategy does not only provide exchange of ideas and cooperation in solving a problem but also promotes higher thinking skills as well as positive attitudes towards learning. According to Zakaria and Ikhsan (2007), cooperative learning experiences promote more positive attitudes toward the instructional experience than competitive or individualistic methodologies. Norah (2015)agreed that in cooperative learning students work face to face to complete a given task collectively. Cooperative learning encourages students to be active participants in the construction of their own knowledge.

However, according to Johnson, Johnson and Smith (2007), cooperative learning is an instruction that involves students working in teams to accomplish a common goal, under some conditions that include the following elements:

1. Positive interdependence: team members are obliged to rely on one another to achieve a goal the goal. If any team members fail to do their part, everyone suffers consequences.
2. Individual accountability: all students in a group are held accountable for doing their share of the work and mastery of all of the materials to be learned.
3. Face-to-face promotive interaction: although some of the group work may be parceled out and done individually, some must be done interactively, with group members providing one another with feedback, challenging, challenging reasoning and conclusions, and perhaps most importantly, teaching and encouraging one another.

4. Appropriate use of collaborative skills: students are encouraged and helped to develop and practice trust-building, decision making, communication, and conflict management skills.

5. Group processing: team members set group goals, periodically assess what they doing well as a team, and identify changes they will make function more effectively in the future.

Cooperative learning is not simply a symposium for students working in groups. A learning exercise only qualifies as cooperative learning to the extent that the five listed elements are present (Felder & Brent, 2007). Apparently "people must be taught how to work in groups as Johnson, Johnson and Holubec (1993) pointed out. Students must therefore be guided to work in groups to accomplish a common goal successfully. Therefore, the basic role of a teacher is to teach students what to do, why they need to do it, how will they do it and who is responsible for it, when working in a group to accomplish a common goal.

2.4.1 Models of Cooperative Learning Strategy

Cooperative learning strategy is quite variable in form (Johnson, Johnson & Holubec, 1993). However, all of the strategies are based on the knowledge that learning is enhanced when people explain their ideas to one another. According to Felder & Brent, (2007) cooperative learning is not simply a synonym for students working in groups. A learning exercise only qualifies as cooperative learning to the extent that the five basic elements identified by Johnson, Johnson and Smith (1998) are present. A record of variety of developed and tested cooperative learning models abound in literature (Guskey, 1990; Slavin, 1990; Shari & Arrends, 1991). Some models framed after these were observed to have achieved the instructional objectives in the area of academic achievement, improved race relations and social skills (Johnson, Johnson & Stanne, 2006). However, all models have the same basic component and characteristics. The models of different formats were proposed by different researchers from their investigations. Some of these models were described as; Students Teams Achievement Division (STAD), Teams Games Tournament (TGT), Team Assisted Individualization (TAI), Peer-led Team Learning (PLTL) Other models include; cooperative integrated reading and comprehension (CIRC), the Jigsaw model, Learning together; Group investigation and the reciprocal teaching approach, Problem sets, Laboratories and projects, Peer editing, Think-pair share, Three-step interview, Round table or Rally Table, Rally Robin, Three-minute interview, Inside-outside circle (Johnson & Johnson, 2000; Felder & Brent, 2007).

Peer-Led Team Learning

In peer-led team learning (PLTL), lectures are supplemented by weekly 2-hour workshops in which students work in six- to eight-person groups to solve structured problems under the guidance of trained peer leaders. The problems must be challenging and directly related to the course tests and other assessment measures. The course professor creates problems and instructional materials, assists with the training and supervision of peer leaders, and reviews progress of the workshops. The materials prompt students to consider ideas, confront misconceptions, and apply what they know to the solution process. The peer leaders clarify goals, facilitate engagement of the students with the materials and one another, and provide encouragement, but do not lecture or provide answers and solutions.

Peer-Led Team Learning (PLTL) was developed by chemistry educators in the 1990s and may be the most prominent group- learning strategy in chemistry education. It is not a cooperative learning strategy by definition, but it shares a number of elements with cooperative learning. The students are confronted with difficult problems and must rely primarily on one another to develop solutions, which promotes positive interdependence, and face-to-face interaction is crucial to the workshop format. Students are tested individually on the knowledge required to solve the problems, and a function of the peer leader is to get team members to explain their understanding to their teammates, both of which provide individual accountability. There is no formal instruction in teamwork skills in PLTL, but informal instruction invariably occurs as the peer leaders facilitate the group interactions. The only cooperative learning criterion that does not appear to be addressed as part of the PLTL model is regular self-assessment of team functioning and it would be trivial to add that in PLTL implementations.

Teams-Games-Tournaments (TGT):- TGT approach is identical to STAD, except students compete with those teams who are at the same performance level. Low and high achievers from each team compete with their counterparts and the top scorers in these “tiered” tournaments win points for their teams.

Team Accelerated Instruction (TAI):- Students study individually but are assigned to teams whose members check and help each other. Students are tested individual, but team rewards are given based on the' number if individual assignments and tests those members complete. The method is useful in highly structured subjects where success depends on mastering pre-requisites.

Student Teams-Achievement Divisions (STAD): This model was originated by Robert Slavin (1990) and his colleagues at Johns Hopkins University. The STAD, model underscores many of the attributes of direct instruction, and it is a very easy model to implement in the science classroom. As in the entire cooperative learning models to follow, STAD operates on the principle that students work together to learn, and are responsible for their teammates' learning as well as their own as derived from Kutnick's (1988) contact theory. Arends (1991) identified some important steps which the teacher should follow in a cooperative learning model. These include: Provision of instructional objectives; Presentation of information, Organization of students to work in learning teams, assisting of team work, Study testing of students and recognition of achievement.

Phase I Class Presentation

The class presentation is a teacher-directed presentation of the material concepts, skills, and processes that the students are to learn. Carefully written and planned objectives should be stated and used to determine the nature of the class presentation, and the team study to follow. Key concepts should be identified as well. The presentation can be a lecture, lecture/demonstration, or audiovisual presentation. You also could follow the lesson plans in your science textbook, including the laboratory activities in this phase of ST AD. Several lessons would be devoted to class presentations.

Phase II: Team Study

In STAD, teams are composed of four students who represent a balance in terms of academic ability, gender, and ethnicity. The team is the most important feature of STAD, and it is important for the teacher to take the lead in identifying the members of each team. Slavin (1990) recommends rank ordering your students in terms of performance. Each team would be composed of high and low ranking student and two near the average. The goal is to attempt to achieve parity among the teams in the class. Teams should also be formed with sex and ethnicity in mind. Each team should be more or less an average composite of the class. Team study consists of one or two periods in which each team masters material that you provide. Team members work together with prepared worksheets and make sure that each member of the team can answer all questions on the worksheet. Students should move their desks so that they face each other in each small team. Give each team two worksheets and two answer sheets (not one for each student).

In the STAD model the following team rules are explained and posted on the bulletin board:

1. Students have the responsibility to make sure that their team mates have learned the material.
2. No one is finished studying until all team mates have mastered the subject.
3. Ask all team mates for help before making the teacher.
4. Team mates may talk to each other softly.

It is important to encourage team members to work together. They work in pairs within the teams (sharing one worksheet), and then the pairs can share their work. A principle that is integral, not only to STAD, but to all cooperative learning models is that students must talk with each other in team learning sessions. It is during these small group sessions that students will teach each other, and learn from each other. One of the ways to encourage deeper understanding is for students to explain to each other their answers to the questions. The teacher moves from group to group asking questions, and encourage students to explain their answers.

Phase III: Test

After the team study is completed, the teacher administers a test to measure the knowledge that students have gained. Students take the individual tests and are not permitted to help each other.

Phase IV: Team Recognition

Team averages are reported in the weekly recognition chart. Teachers can use special words to describe the teams' performance such as science stars, science geniuses, or Einsteins. Recognition of the work of each team can occur by means of a newsletter, handout, or bulletin board that reports the ranking of each team within the class. Teacher reports outstanding individual performances.

Jigsaw Model

Jigsaw is a cooperative learning structure applicable to team assignments that call for expertise in several distinct areas. For example, in a laboratory exercise, areas of expertise might include experimental design, equipment calibration and operation, data analysis (including statistical error analysis), and interpretation of results in light of theory, and in a design project the areas might be conceptual design, process instrumentation and control, safety and environmental impact evaluation, and cost and profitability analysis.

Suppose four such areas are identified for a project. The students are formed into teams of four, and either the instructor or the team members designate which member will be responsible for each area. Then all the experts in each area are given specialized training, which may involve getting handouts or presentations by the course instructor, a faculty colleague, or a graduate student knowledgeable in the area in question. The students then return to their home teams and complete the assignment. The teams count on each member to provide his or her expertise, and if an expert does a poor job, the quality of the final project is compromised and everyone's grade suffers. Moreover, if the students are tested on all of the areas of expertise, the overall learning from the assignment improves dramatically. The tests require all students to understand the entire project, and not just the part that they were the experts in (individual accountability), and the experts have the responsibility of transmitting their expertise to their teammates (positive interdependence).

A typical jigsaw activity involves students becoming experts, and then teaching their group about what they have learned. For example, in a class using the Jigsaw strategy the teacher has a general topic of which the class is to learn more about in their cooperative learning groups. The topic is divided into separate sections, and each individual is given a different sub-topic to research by using class notes, text books, etc. Each student becomes an "expert" on the sub-topic. These experts then get together into groups of students with the same topics, to discuss what they have learned about the sub-topic. These meetings serve several useful functions, including: checking their understanding of the material, review, revise, clarify concepts, etc. After this step, the students meet together in their original groups, and each of the individual students, now "experts", are responsible for teaching their teammates about their topic of study. The teacher then provides support by listening to the following discussions, noting difficulties or providing more in-depth knowledge where necessary (Koppes, 2002 & Norah, 2015).According to Doymus, (2007) and Sahin, (2010), Jigsaw technique allows students to actively participate in learning process. Students feel more comfortable about their roles when subjected to to this technique constantly. Some evaluations of the groups could improve the effectiveness of the jigsaw technique by making each student have a sense of responsibility for their group performances. Jigsaw improves students' learning because of the following reasons; a) it is less intimidating for many learners, b) it increases the number of students' involvement in the classroom, c) it reduces the necessity for competitiveness, and d) makes students less dependent on the teachers as expert in the leading environment (Qiao, & Jin, 2010).

Jigsaw was first developed by Elliot Aronson in 1978 which later attracted attentions of many educators to conduct researches on the importance and application of the jigsaw technique. After the researches on the Jigsaw technique, some changes were made in the application process of the technique and new types of it appeared. Every type of the jigsaw technique follows the same stages but there are some differences of practices between different jigsaw techniques. This is to say that the use of jigsaw is very flexible. By the changes in the application process, the technique began to be referred to with different names. The jigsaw technique provides learners with the chance to be dynamically involved with the learning procedure. With different introductions to this technique, students must feel more at ease with their roles (Doymus, 2007; Sahin,2010 & Norah, 2015).

Researches on approaches to jigsaw technique reveal that six approaches are available: (1) Jigsaw, (2) Jigsaw II, (3) Jigsaw III, (4) Jigsaw IV, (5) Reverse Jigsaw, and (6) Subject Jigsaw (Sahin, 2010).

1. **Jigsaw (otherwise called Jigsaw I)** was developed by Elliot in 1978. Students are divided into 4 or 5 groups called home groups where each group consists up of small number of students. Topics in segments are given to individual members of each group to become expert on the topics. Each student from home groups after becoming expert move on to form an expert group working with members assigned the corresponding topics. Upon returning to their home groups, each one, in turn, teaches the group. Students are all assessed on all aspects of the topics (Norah, 2015).
2. **Jigsaw II** was developed by Slavin in 1987. In jigsaw II, home groups and expert groups are also formed. Each student on the team, as in jigsaw becomes an expert on the topic assigned to him/her working with other members assigned the corresponding topic in the expert group. A test of expertise is given to expert groups before they return to home groups. Upon returning to their home groups, students, in turn, teach the segment they are expert on to their teammates.Students are all assessed on all aspects of the topics (Sahin, 2010).
3. **Jigsaw III**, developed by Stahl in 1994, has an addition of a cooperative test review process. The cooperative test review involves reconvening the home groups and reviewing the process. Jigsaw III, a modification of Jigsaw II, is

modified to increase students' interaction in the groups (Doymus, 2007; Sahin, 2010).

4. **Jigsaw IV**, developed by Holliday in 2000, has three prominent features; an introduction, quizzes, and re – teaching after individual assessment. The teacher introduces the lesson, assign students to home groups and all students assigned topics to read move to expert group to work with other members from other teams assigned the corresponding topic. Students return to their home groups and are assessed on all aspects of the topic. The teacher re – teaches any material that was not clear to students after individual assessment. Test is finally given to students individually and scores are combined to find overall team score (Jansoon, Somsook, & Coll, 2008; Sahin, 2010).
5. **Reverse Jigsaw:** In this technique, which was developed by Heeden in 2003, students in the expert groups teach the whole class rather than return to their home groups to teach the content. It differs from all forms of jigsaw during the teaching portion of the activity (Heeden, 2003; Sahin, 2010).
6. **Subject Jigsaw:** This technique was developed by Doymus in 2007. It is used in group – based learning in which students need to cooperate with their teammates in order to achieve personal goals. Each student is like a piece of jigsaw puzzle who needs to understand and learn the subject completely (Doymus, 2007; Sahin, 2010; Fini, Zainalpour & Jamri, 2012).

Olorukooba, (2001) expressed that Elliot used cooperative learning specifically to bring children of different races and ability together. He based the theory and practice of the Jigsaw model on social psychological research, mutual interest, co-ordinated efforts, trust and helpfulness amongst group members. Also, academic performance was found to improve amongst ethnic-minority pupils. Socially, there was substantial development in inter-ethnic acceptance, concern and trust. Group members also showed an increased ability in taking on other perspective in role taking and promoting social sensitivity. According to Olorukooba, (2001) Elliot proposed the following steps to be followed while adopting Jigsaw model.

1. divide students into 5 or 6-person jigsaw groups. The groups should be diversed in terms of gender, ethnicity, race and ability.
2. appoint one student from each group as the leader. Initially, this person should be the most mature student in the group.
3. divide the day's lesson into 5 – 6 segments corresponding to the number of the groups.
4. assign each student to learn one segment, making sure students have direct access only to their segment.
5. give students time to read over their segment at least twice and become familiar with it. There is no need for them to memorize it.
6. form temporary "expert groups" by having one student from each jigsaw join other students assigned to the same segment. Give students in these expert groups time to discuss the main points of their segments and to rehearse the presentations they will make to their jigsaw group.
7. bring the students back into their jigsaw groups.
8. ask each student to present her or his segment to the group. Encourage others in the group to ask questions for clarification.
9. float from group to group, observing the process. If any group is having a trouble (e.g, a member is dominating or disruptive), make an appropriate intervention. Eventually, it's best for the group leader to handle this task. Leaders can be

trained by whispering an instruction on how to intervene, until the leader gets the hang of it.

10. give quiz at the end of the session on the material learnt.

Peer Editing Model

When teams turn in written lab reports and/or give oral presentations, the usual procedure is for the instructor to do the critiquing and grading. A powerful alternative is peer editing, in which pairs of groups do the critiquing for each other's first drafts (written) or run-throughs (oral). The groups then revise their reports and presentations taking into account the critiquing teams' suggestions and then submit or present to the instructor. This activity lightens the grading load for instructors, who end up with much better products to grade than they would have without the first round of critiquing. If a grading checklist or rubric is to be used for grading the team reports (which is always a good idea), it should be shared with the students before the reports are written and used for the peer editing. This practice helps the students understand what the instructor is looking for and invariably results in the preparation of better reports, and it also helps assure that the peer critiques are as consistent and useful as possible. If several rounds of peer editing are done and the instructor collects and grades the checklists or rubrics for the first one or two rounds, the students will end up giving much the same rubric scores as the instructor gives, and in good classes the instructor may only have to do spot checks of peer grades instead of having to provide detailed feedback on every report.

Cooperative Integrated Reading and Composition (CIRC)

Cooperative Integrated Reading and Composition (CIRC) was developed for grade level reading and writing institution in the elementary grades. Instruction is primarily based on basal readers and involves direct instruction in reading comprehension, integrated writing, and language arts using a writing process approach

Heterogeneous teams are composed of members of at least two different reading groups who read to one another answers answer questions about the story, practice spelling and vocabulary words, and wrote on a topic related to the basal story. Team members receive points based on individual performance on quizzes and composition which are “added” to produce a team score. Achievement criteria are specified; teams that meet the criteria receive certificates.

Learning Together Model

Johnson and Johnson have emphasized group process in their generic model characterized by explicit and sustained teaching of structures social skills. Most of the research by the developers and their associates compared the cooperative goal structure with a competitive condition and with an individualistic condition. Heterogeneous groups of two to six students with maximum variation in levels of achievement are recommended. In addition the Johnsons have suggested unmotivated students be placed in groups with on task students. In some cases, students are permitted to work together to complete a single worksheet or product for a group grade (Jonson, Johnson & Holubec, 1990

Co-op Co-op and Cooperative Structures

Like group investigation, co-op co-op is based on heterogeneous small groups studying a subtopic as part of a whole class investigation. Co-op co-op encourages library research, interviewing, original data gathering and creative products. Students and teachers are self-evaluated on team presentations, their written products, and on their contributions to the team. Kegan (1989) has also encouraged the use of short term cooperative structures developed by other educators as well as him. Two examples of these structural cooperative strategies are think pair share and numbered heads together, which are variations of group discussion.

2.4.2 Studies on Cooperative Learning Strategy and Academic Performance

A record of different instructional strategies/packages have been consistently and successful in use to improve students' achievement in science. Koppes, (2002) & Norah, (2015) affirmed that sensitive and controversial issues in science could be most appropriately taught when cooperative group approach is utilized. Recent studies suggest that sixth – grade students who are in cooperative groups for their science class showed higher achievement levels of satisfaction than students in whole group conditions (Maheady, Harper & Mallette, 2001). More brilliant contributions to scientific knowledge take place whenever students talk together; hence, the practice of group work for effective science teaching is an important feature of any science teaching strategy (Bilgin & Geban, 2006). Teachers should therefore guide students to discharge individual roles in a group work in order to achieve a common goal.

The studies on cooperative learning strategies which have repeatedly shown increased academic achievement include those of Steiner, Stromwall, Brzuzy and Gardes (1999), Johnson and Johnson (2000) and Johnson, Johnson and Smith (2007) reported significantly higher gains on both normative and criterions measures of academic testing for students in cooperating learning groups.

In other studies (Chang & Mao, 1999; Wamser, 2006 &Killic, 2008), cooperative learning strategies were found to improve students' performance and cognitive achievement in science classes.Hennessy and Evans (2006) reported higher achievement resulting from cooperation groups in a wide variety of subject areas including spelling, social studies, health and language. Students on cooperative groups were able to master and retain information better than students in individual or competitive situations (Gubbad, 2010; Tsay & Brady, 2010).

Academic performance of students has been found to be enhanced by the use of cooperative learning (Lampe, Rooze & Tallest – Runnels, 1998; Olorukooba, 2006 &Doymus, 2007). Steven and Slavin, (1995) stated that the fact that it has been linked to increase in the academic achievement of learner at all ability levels is another reason for its use. Webb, Tropper, and fall (1995), Doymus, Karacop and Simsek (2010); Norah, (2015) in their contributions noted that cooperative learning activity engages the students in the learning process and seeks to improve the critical thinking, reasoning, and problem – solving skills of the learner.

While research efforts on cooperative learning indicate that it enhances students' performance (Olorukooba, 2006; Johnson, Johnson & Smith, 2007; Davidson and Major, 2014), Lampe, Rooze and Tallent – Runnels (1998) and Anthony (2013) stated that peer interaction is central to the success of cooperative learning as it relates to cognitive understanding. They further noted that comprehension is facilitated. Lampe et- al (1998) again emphasized that as learners, some of who might normally "turn out" or refuse to speak out in a traditional setting, become actively involved in the learning strategy, when used appropriately, can enable students to move beyond the next, memorization of basic facts and learning lower level skills. This method which results in cognitive restructuring leads to an increase in understanding of all students in a cooperative group (Ajaja & Eravwoke, 2010).

Several studies (such as Ojo, 1997; Alebiosu, 1998 & Yusuf, 2005) have examined the effect of cooperative learning methods on students' academic achievement. For example, Ojo (1992) compared cooperative, competitive and individualistic strategies in science classes and found that students who were exposed to cooperative methods learned and retained significantly more information than students taught by the other two methods. Alebiosu (1998) found similar results in a study involving high school chemistry classes taught by cooperative and individualistic methods. Also Yusuf (2005) reported significantly better achievement in students exposed to cooperative learning method in a study carried out among junior secondary school students. Cooperative learning encourages students to be active participants in the construction of their own knowledge (Webb, Troper, & Fall, 1995; Okoli, 2006). A study conducted by Zakariya, Chin, and Daud (2010) found that cooperative learning improves students' achievement in mathematics. Also, (Shimazoe & Aldrich, 2010; Gupta & Pasrija, 2012)Cooperative learning promotes deep learning of materials and helps students to achieve better grades.

Researchers have been conducted in different parts of the world to determine the effects of cooperative leaning strategy on students' academic achievement and significant improvement were recorded. Kilic (2008) conducted a research to determine the effects of the Jigsaw technique used in collaborative learning and that of classical learning method on the academic performance of the students, on the learning of the concepts in the principles and methods of teaching course. The research was carried out on the second year students of the Ataturk University primary school teaching division in the principles and methods of teaching course. A total of 80 students where used in the research in the form of an experimental group where the jigsaw technique (n=40) and a control group (n=40) where the classical learning method has been applied. At the end of the evaluation, there was a statistically meaningful difference in favour of the experimental group.

In their study, Zakaria, Solfitris, Daud & Zainul Abidin (2013), to determine the effects of cooperative learning on students' mathematics achievement in secondary school students in Pekanbaru, Indonesia. Their study also determines students' perception concerning cooperative learning. The sample of the study consisted of 61 form three students. A pre-test was given before treatment in order to control the differences of dependent variables. After treatment, a post – test was administered to both groups. Two types of instruments were used to collect the data: the mathematics achievement test and open-ended questions on cooperative learning. The pre-test and post-test were analyzed using t-test. Content analysis was used for the open-ended questions on cooperative learning. The results of the study showed that there was a significant difference of mean in students' mathematics achievement between the cooperative group and the traditional group. Content analysis data revealed that students in the cooperative group were able to increase the understanding and to develop their self – confidence. Also in Kenya, (Wachanga & Mwangi, 2004) conducted a research to examine how the cooperative class experiment (CCE) teaching methods affect students' achievement in chemistry. The research was conducted using a non-equivalent control group design with 521 randomly selected students. The study found that CCE method facilitated students' chemistry learning more than regular methods. One-way ANOVA was used on students' post-test chemistry achievement test (CAT) scores to estimate the effect of CCE on students' CAT. The difference in achievement among the groups and the control group was found to be significantly different i.e. the experimental group performed more than the control group.

In Nigeria, Alebiosu (1998) investigated the effects Student Team Achievement Division- STAD and Jigsaw II on senior secondary schools student's cognitive achievement, attitude towards chemistry and achievement in practical skills in chemistry. The researcher used 252 students in intact classes from nine secondary schools randomly selected to the treatments and control groups. The result of the study showed that the treatment group performed significantly better in cognitive achievement attitude and in practical skill. In 2001, Olorukooba studied the effects of cooperative instructional and traditional method of instruction on academic achievement of students and their retention of chemistry concept and attitude of male and female students towards cooperative instructional strategy. The study comprised of 137 experimental subjects that were taught using cooperative instructional method and 127 controls, were taught using the traditional lecture method. The findings showed that the experimental group performed significantly better in the achievement test, than the control group. The use cooperative instruction strategy was recommended based on the findings of the study.

Adesoji and Ibrahim (2009) studied the effects of Student Team Achievement Division- STAD strategies and mathematics knowledge on learning outcomes in chemical kinetics. The results showed that STAD strategy had the potential to improve students' learning outcome in secondary school chemistry. Also Olatoye, Aderogba and Aanu (2011) investigated the main and interaction effects of cooperative and individualized teaching methods on senior secondary school students' achievement in organic chemistry. The study selected 156 students and the results showed that there is significant main effect of treatment on students' achievement in chemistry. However, cooperative method is significantly better than the individualized method.

The objective of this study therefore is to study the impact of cooperative learning strategy (CLS) on science process skill (SPS) Acquisition and Academic Achievement in chemistry. The studies cited above did not indicate the effect of CLS on SPS and were conducted in different environments. Also, there is no empirical evidence on this learning strategy. Therefore, it is intended in this study to determine the effect of CLS on SPS acquisition and academic achievement in the learning of chemistry by Senior Secondary School students.

2.5 Science Process Skills (SPSs)

The shift from the teacher-centred method of teaching to child-centred activity based method which encourages and develops in the child the spirit in inquiry; an attempt to make students fully aware as well as understand the ways scientists work; and also the equipping and preparing students for their possible careers in science and technology led to the development of process skills (Akinbobola, 2006). The science process skills are synonymous to science the process approach. In the process approach to teaching of science according to Usman (2012), emphasis is on teaching the children to develop process skills, which can be used in solving problems. Very little emphasis is placed on content or subject matter which can become out-dated or in need of modification in the light of new discoveries. Situation and activities are devised by the teacher in which the children will have the opportunity to raise questions and practice scientific skills to solve problems.

Science process skill have been described as mental and physical ability and competencies which serve as tools needed for the effective study of science and technology as well as problem solving, individual and societal development (Aydogdu & Kerseicioglu,2005). According to Arokoyu & Nna, (2012) and Maeve, (2013), science process skills (SPSs) are the thinking skills that scientists use to construct knowledge in order to solve problems and formulate results. The scientific method, science thinking and critical thinking are also terms that have been used to describe these skills but last two decades, the phrase “science process skills” has become more common. When scientists conduct investigations, they use SPSs to discover scientific knowledge which is explained as describing, predicting, explaining and adapting to phenomena of the natural world (Carin, Bass & Conant, 2005; Ozgelen, 2012). It is opined by (Ango, 2002; Huppert, Lomask & Lazarocitz, 2002) that scientific process skills (SPSs) include skills that every individual could use in each step of his/her daily life by being scientifically literate and increasing the quality and standard of life by comprehending the nature of science. Therefore these skills affect the personal, social and global lives of individuals.

The SPSs are a necessary tool to produce and use scientific information, to perform scientific research and to solve problems. These skills can be gained by students through certain science education activities. For example the purpose of learning by using a research study is to help teach the scientific process. The students undertaking a scientific research study can learn the processes of science (Carin, Bass & Conant, 2005). Science process according to Vitti and Torres (2006) occurs naturally, spontaneous in our minds. By logically breaking down the steps in our thinking, we can use science process to find out how to answer our questions about how the world works. Science process is not just useful in science, but in any situation that requires critical thinking. Science process skills include observing qualities, measuring qualities, sorting/classifying, inferring, predicting, experimenting and communicating.

Process skills in science characterize the method through which scientific knowledge is generated, established and developed. The development in pupils of these processes constitutes an important aspect in science education. The familiarization with the processes of science to the teachers is essential if they are to achieve aim (Muzumara, 2007). According to (Aderogba & Oyelekan, 2010;Ozgelen, 2012) Science can be classified into major components, namely the product and process, though the ethics of scientists inclusive. The product, otherwise known as the content is made up of scientific concepts, facts, principles, theories or law of science. The process of science deals with the way scientists carry out their activities such as, the techniques of gathering, analyzing and interpreting data or information. These techniques involved specialized abilities referred to as "skills". Thus, scientific process is accompanied by means of skills. The American Association for the Advancement of Science (AAAS) sees science process skills as a group of transferable activities related to science and they give a picture of the scientist behaviour. The AAAS sponsored the development of materials which gave rise to about thirteen science process skills. The Nigerian Educational Research and Development Council (NERDC) slightly modified the AAAS skills to fifteen. These are observation, classifications, counting/number relations, measurement, communication, predication, inference, formulating hypothesis, controlling and manipulating variables, interpreting data, making operational defining, experimenting, raising questions, manipulating techniques and building mental models (Aderogba & Oyelekan, 2010).

Some researchers (Seviley, 2011& Ozgelen, 2012), argued that SPSs can be explained by a two-level hierarchical model of basic and integrated skills. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. Basic science processes are vital for science learning and concept formation at the Primary and Junior Secondary School levels. More difficult and Integrated Science Process Skills are more appropriate at the secondary and tertiary school levels for the formation of modes, experimenting and inferencing. Hence both basic and integrated SPSs are relevant and appropriate at senior secondary schools in Nigeria (Akinboboa & Afolabi, 2010). Science Process Skills have been described as mental and physical abilities, competencies which serve as tools needed for effective study of science and technology as well as problem solving, individual and societal development (Akinbobola & Afolabi, 2010).

The American Association for the Advancement of Science (AAAS) and National Educational Research and Development Council (NERDC) classified the science processes skills into fifteen (Akinbobola & Afolabi, 2010; Aderogba & Oyelekan, 2010). These are: observing, measuring, classifying, communicating, predicting, inferring, using number, using space/time relationship, questioning, controlling variables, hypothesizing, operational definition, formulating models, designing experiment and interpreting data. According to Ango (2002) and Akinbobola & Afolabi, (2010), Science Process Skills can be classified into two categories; basic science process skills and integrated science process skills. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. Basic science processes are vital for science learning and concept formation at the primary and junior secondary school levels. More difficult and integrated science process skills are more appropriate at the secondary and tertiary school levels for the formation of models, experimenting and inferencing. Hence both basic and integrated science process skills are relevant and appropriate at the senior secondary schools in Nigeria.

According Ango (2002), the basic science process skills comprised of observing, measuring, classifying, communicating, inferring, using number, using space/time relationship and questioning while integrated science process skills are controlling and manipulating variables, hypothesizing, defining operationally, formulating models, designing experiment and interpreting data. It was opined by Ozgelen (2012), that the basic SPS consist of observing, using space/time relationships, inferring, measuring, communicating, classifying and predicted. Integrated SPS include controlling variables, defining operationally, formulating hypothesis, interpreting data, experimenting, formulating models and presenting information. The basic SPS is an essential tool needed by scientist to construct new knowledge and solve problems. While the integrated SPS requires a more advanced knowledge base. For instance, identifying and controlling variables is an essential skill for successfully managing scientific investigation. These processes have to be defined and considered in a scientific sense in order to convey a scientific meaning. They have to relate to scientific activities that can lead to the acquisition and development of scientific knowledge (Carin et-al, 2005; Akinbobola & Afolabi, 2010; Ozgelen, 2012).

The Science Processes Skills (SPSs) are described in various ways, all of which suffer from the problem of drawing a boundary between them. For example, we cannot deal with observation without necessarily involving hypothesis and some degree of investigation. While it is important to appreciate the fact that observation forms the basis for any scientific investigation, involving other processes cannot be avoided. There are always overlapping processes in linking and testing ideas of scientific nature (Usman, 2000; Atkamis & Ergin, 2008).However, in developing processes skills in students, science teachers need to focus on some of the indicators of the processes being developed (Muzumara, 2007). Each of the processes identified by different authors above was explained briefly in the following.

Observation: is perhaps the most fundamental scientific process in which an individual uses his/her senses to obtain information about a given phenomena, event or situation. In order to make relevant observations we have to have prior theories, conceptual apparatus that will guide the observations, (Vitti & Torres, 2006; Muzumara, 2007). According to Usman (2012), children may look at living and non- living things without noticing certain characteristics or details. They have to be trained to see similarities and differences. They have to be able to identify colours, recognize smells, distinguish between a rough surface and a smooth one, a loud noise and a soft one. Observation relies mainly on the use of the eyes but the other senses are often used at the same time. It is reported by Muzumara (2007) that pupils in science lessons can be trained to become better scientific observers by extending the relevant theoretical framework they bring to any specific observation task and to present the task in a way, which engages their active attention. Indicators are proposed to science teachers to use to show that their students are observing if they:

- Use aids to the senses to notice details,
- Discern the order in which events occur,
- Compare and contrast observable features in objects,
- Identify specific patterns in objects or occurrences.

Classification: This is the grouping, sorting and arranging of things into recognized patterns on the basis of observed and measured similarities and differences among the factors considered (Ango, 2002 & Aderogba & Oyelekan, 2010). According to Ango (2002), classification as a science process skill is important because it contributes to the extent to which students understand, conceptualize and attach meaning to scientific ideas. Classification keys are important for conceptual organization. They facilitate students' understanding and promote sound conceptual structure by allocating items within a conceptual scheme. Classification keys also facilitate students' ability to retrieve information from a conceptual scheme. In a view expressed by Usman (2012), to be able to classify properly we have to be good observers. Classification implies sorting things according to types and properties. There are many ways in which classification can be carried out. Objects of the same colour can be put together, or they can be grouped by size, big and small. Animals can be classified by the number of legs or whether they are domestic or wild. People can be classified by sex, male or female, or by age, qualifications or marital status. Also Muzumara (2007), stressed that teachers may know that their students have developed the ability to classify if they:

- Sort out objects and events according to similar characteristics,
- Remove odd objects from similar ones,
- Use basic scientific information models,
- Recognise differences and similarities of objects.

Counting/ Number Relations: As viewed by Usman (2012), is a skill which involves being able to use numbers in addition, subtraction, multiplication and division. This skill is specifically taught in arithmetic and mathematics lesson but can also be included in science lessons. When we need to know how many seeds there are in an Albisia pod, we have to count the number. If we are measuring the annual rainfall, we have to add up the number of centimeters of rain we collect each time it rains. Counting numbers then, is a skill which we can help children develop during science lessons. While Aderogba and Oyelekan (2010), defined counting as identifying sets and their numbers. It has to do with identifying and naming the ordinal relationship among numbers.

Measurement: Aderogba and Oyelekan (2010), viewed measurement as the use of measuring instrument which utilize standardize units to describe the properties of objects such as height, width, length, area, volume, mass and time. Measurement is one of the main ways in which students receive feedback from their scientific inquiry (Ango, 2002). Measuring entails evaluation, which entails value judgement. According to Usman (2012), there are many different ways of measuring. For example, we can measure volume in cubic centimetres, cubic metre or litres. Length, height and width can be measured in millimetres, centimetres, metres or kilometres. Area can be measured in square centimeter, square metres or hectres. To be able to measure accurately is a skill which needs a lot of practice.

Communication: This can be any of the several procedures involved in various media which carries information from one person to another. Communication in science involves the use of various conventions of representation which help in organizing and conveying it effectively. The use of graphs, charts, tables, symbols, diagrams, models, and formulae makes communication in science easy and helps convey more information than the words can do. It is important for science teachers to expose their students to all these means of communication and encourage them to develop skills in writing and speaking using the appropriate scientific terminologies. Students should be able to interprete and translate the different conventions used in order to make sense of the scientific meanings they convey. Students can be seen to communicate if they:

- Can discuss, listen or write their ideas with clear meanings,

- Can write their observations during investigations,
- Can search relevant information from many sources such as books, magazines, internet, radio and television programmes.
- Use scientific terms correctly so that they are understood by others.
- Use appropriate conventions such as symbols, charts, diagrams, or tables to convey information (Muzumara, 2007).

Ango (2002) strongly believed that communication is a critical aspect of scientific investigations. Without it, scientific investigation would be pointless. No one, other than the original investigator would be able to the results or findings of the investigator. Thus, the skill of communication must be included in the early stages of teaching band studying of science. Thoughts, ideas, research findings and all sorts of vital information need to be communicated for awareness, learning, instruction and other purposes. There are many means of doing so, for example, speech, writing, pictures, diagrams, graphs, mathematical formulae, tables and figures. In his view (Aderogba & Oyelekan, 2010), communication is the making known accurate records of experimental results through the use of maps, graphs, tables, diagrams, charts, write-up and oral discussion. While Usman (2012), says talking, writing, drawing and using gestures with the hands are ways in which people communicate with each other. Some people speak clearly and when they describe something we are easily able to understand what they are talking about. Others are able to draw, inform of a picture, what they want to communicate to us. To make others understand what we have in our minds we need to communicate, and to communicate well is a skill which we have to develop. Young children need to be taught how to communicate so that they can pass on their ideas, needs and problems to others. Communication is a skill they will need in a profession they will later take up. Scientists have to be able to communicate their findings to others and in addition to talking and writing they have to draw graphs and children to illustrate their results. Children in the high classes of their primary schools can be taught how to construct bar graphs as a form of communication

Interpreting data: is a skill where answers are sought to question or hypothesis under investigation (Aderogba & Oyelekan, 2010). Scientific inquiry is empirical in nature. Through observation and experiments, data are gathered. Once collected, the data need interpretation so that meaning and sense can be related to the data. Interpreting and inferring are critically determinant activities of science. Information gathered from scientific investigation usually is not readily useful and meaningful to other scientists and the wider community. Data have to analysed and interpreted, and inferences have to be made to produce and extend knowledge which is to have usefulness and meaningful application for life.

In his words, Usman (2012) expresses that once an experiment has been performed and the data recorded, the next step is to look at the data to see if some conclusions or generalizations can be made. In the experiment mentioned in the previous paragraph the results have to be look at carefully and interpreted before any conclusion can be made as to whether one type of soil is better than the other. Interpreting involves finding a pattern, trend or relationship inherent in a set or collection of data. It is essential to avail enough data in order to come up with meaningful interpretations that can lead to a conclusion. Recognising the limitation of a given set of details is important before one draws a conclusion (Muzumara, 2007). The indicators (according to Muzumara, 2007) that show that students are able to interprete and draw conclusions may include: Putting data together to find out tends, patterns and relationships, Identifying relationships and patterns, Using graphs, charts, and diagrams to show relationships for their data, Ensuring that a pattern or relationship is checked against all the available data, Showing cautions in making generalizations, considering factors that may influence their conclusions.

Prediction: Aderogba and Oyelekan (2010), sees prediction as forecasting or extrapolating on the basis of observations. It was opined by Muzumara (2007), that prediction is a statement about what may happen in the future or what will be found that has not yet been found, usually based on some hypothesis or previous knowledge. For one to make a meaningful prediction there should be some facts or evidences available. This makes a prediction different from an ordinary guess, which cannot be justified in terms of hypothesis or evidence. A science teacher can tell that the students are able to predict if they:

- Make use of the knowledge gained to state what may happen
- Use patterns in evidence to interpolate is extrapolate
- Distinguish a predication from a guess
- Justify what will happen based on the available evidence and past experience
- Identify the limitations in making assumptions about a pattern that apply beyond the range of evidence
- Examine factors that may affect their predictions

Inference: This is concluding or reacting an opinion from facts using existing observations, measurement, and the like and then devise an explanation on the existing data (Aderogba, 2010). According to Ibrahim (2012), inferring is viewed as giving an explanation for a particular object or event. To infer means to deduce to imply or even to conclude. Inferences usually involved cause and effect relationship, people can infer when there is very little evidence to support their inference. Such inferences are a bit like wild guesses. Some scientists have eventually discovered very important information theories beginning with an inference based on very little evidence. If you infer however, it is normally better to have as much evidence as possible and then you are more likely to infer correctly (Usman, 2012).

Formulations Hypothesis: Hypothesis has been described as an intelligent guess (Usman, 2012). When we don't know the cause of a particular happening or event, with a little bit of evidence we might guess what the cause is when we guess in this way we are formulating hypothesis. In the process of formulating this hypothesis we had made an inference as well. Further investigation will reveal whether we have guessed correctly or not. If we were correct in our hypothesis we can accept it, if we were incorrect we have to reject our hypothesis. A hypothesis can be formulated about something that will happen in the future. It is opined by Muzumara (2007) that students can demonstrate that they are hypothesising if they:

- Suggest explanations, which are consisted with the evidence
- Recognize the provisional nature of any explanation
- Recognize that there can be more than one possible explanation of phenomenon or events
- Suggest explanations which are consisted with scientific concepts and theories
- Use previous knowledge and understanding in trying to come up with explanations
- Seek causes and explanations for peculiar or unfamiliar situations

Controlling and Manipulating Variables: A variables is anything in an experiment that can change and affect the results. Manipulating and controlling that relate to situation or events are done purposely to determine causation (Ibrahim; Umasn, 2012). According to (Aderogba & Oyelekan, 2010), controlling and manipulating variables involve a situation whereby an investigator deliberately controls and manipulate the conditions which determine the events in which he is interested.

Experimenting: This is creating situation which enables an individual to investigate possible causes and effects relationship among variables. In other words, it may involve probing the effects of some variables (independent) and other variables (dependent) (Aderogba & Oyelekan, 2010). In his view Muzumara (2007), experimenting is an activity devised and set up to test a hypothesis. Effective experiments rely on a wide range of knowledge, understanding and skills when faced with a problem, a scientist designs an investigative procedure to try to find the answer to his problems. This is referred to as experiment by trial and error (Usman, 2012). Report was also provided by Muzumara (2007) that students are able to experiment if they:

- Can identify dependent and independent variables
- Can control variables
- Can identify which variable is to measured
- Can make measurements using appropriate apparatus
- Can pose questions on what they want to investigate
- Can suggest ways of testing the ideas

Raising Question: Questioning is a skills that means critical and probing questions on the basis or previous or present observation (Aderogba & Oyelekan, 2010). According to Ango (2002), posing questions is one of the most commonly used process skills of scientific inquiry. It is also part and parcel of everyday classroom teaching and guided study activities. Whether irritated by teacher, students or both a posing questions, establishes a critical basis for classroom communication. Even is a science classroom is completely devoid of apparatus and chemicals for demonstration and experimentation, teachers and student can skill ask questions of each other. And the questions constitute an important a venue for teachers and students to make science lessons likely and involving. Usman (2012) explains that, in order to solve any problem the scientist has to ask himself, or other, relevant questions, to get to the root of the problem. Question beginning with the words how, when, why, by, what, means, are often employed. Raising question is a skill which comes into nearby all forms of investigation. Students must be trained first not to be passive listeners but to ask question and then secondly to ask the right questions which will lead to answers.

Making Operational Definitions: This is defining concepts within the context in which they are used in a particular instance. This ensures precision and makes it possible for attention to be focused on the phenomena under investigation (Aderogba & Oyelekan, 2010). In his words consists of developing statements that present concrete descriptive of an object or events by telling one to do or observe. While Usman (2012), says when conducting an investigation into some phenomena one sometimes come across something which seems to occur with expected frequency. No known name might exist which can be attributed to the thing in question. A temporary or tentative definition as therefore made up until more is known about it.

Manipulating Techniques: these deal with the display of manual skills. It is the way an individual operates or handles scientific activities skillfully (Aderogba & Oyelekan, 2010). Conceptions of contemporary best practice of teaching and study's emphasize that students should be involved in the study process through manipulation of equipment and objects and through participation in any scientific activities pertinent to a given situation in effective guided study (Ango 2002). Due to the necessity to teach children how to manipulate things early in life, Usman (2012) puts that, children and need to be given the opportunity to practice their skill in handling objectives and living things. In the world today many of the things we use in everyday life require a delicate and careful touch.

Formulating Mental Models: According to (Aderogba & Oyelekan, 2010), this involves formulates mental model from hypothesis that are already accepted. The models include charts, diagrams and pictures. In order to sum up a number of different events that occur in a definite sequence, it is often convenient to draw a picture or graph of what takes place. It has been found children and even adults remember better when picture are presented to them about what they are studying. This is because a picture is quite easily imprinted on the mind. Most mental models originate from a pictorial representation of the subject being studied. Mental models which are not picture are usually called concepts. For example, it will be difficult for students to remember concepts of carbon cycle explained in words, but when presented in a diagram, they can easily from a mental picture of all the sequence of events that occur in the cycle (Usman, 2012).

2.5.1 Studies on Science Process Skills (SPSs) and Academic Achievement

The Nigerian Educational System needs a complete overhaul. It is disheartening to know that all is not well with the educational sector after five decades of independence (Aderogba & Oyelekan, 2010) and four tenure of democracy. Studies by (Odubunmi, 2003; Akindehin, 2005 & Aderogba, 2006) revealed that the standard of education in the country is declining and institutions of learning are believed to have been unable to match in performance with the certificate they possess in terms of proficiency and self-reliance. In recent years, the Nigerian educational system has experienced some changes in policies. One of such changes can be seen in the restructuring of the 6-3-3-4 system of education. However, only few meaningful innovations have taken place in the country.The world is currently in the jet of science and technology. The entire universe is now a global village because all activities going on in any part of the world can be transmitted live to other parts of the universe simultaneously as it is occurring. Science and technology are the bedrock of the development of any nation (Aderogba & Oyelekan, 2010). Science and technology of a nation can only be strengthen when the education is strong enough to tackle challenges of teaching and learning of science.

Problems exist with the teaching and learning of science in Nigeria. Results of studies conducted by Owoyemi and Adesoji (2012) revealed that there were low enrolment of students in the science subjects like chemistry and general poor academic performance of science students in senior secondary school certificate examination conducted by WAEC and NECO. From the foregoing, to foster high academic standards a complete transformation of the Nigerian educational system is inevitable (Aderogba & Oyelekan, 2010).

Studies conducted by science educators (Roth, 2004; Aktamis & Urgin, 2008; Akinbobola & Afolabi, 2010; Ozgelen, 2012 & Oloyede, 2012) have identified science process skills as expedient for quality science teaching and learning. Studies aiming to equip students with science process skills have concluded that students acquire each science process skill through certain stages (Saat, 2004; Arokoyu & Nna, 2012). These stages have been identified as recognition of scientific process, making habits, and automation. At the stage of recognition, a student recognize the skill and related terms either in lower grade chemistry classes or in the learning environment developed by the research. At the second stage, the student's familiarized with the process skills and can provide different example related to these skills, but cannot use them in different areas as she/he is experiencing a mental confusion. At the third stage, she/he can easily define the terms related to the skills and can apply them to other situation. Facilities should be used efficiently and environment should employ student-active learning process for students to go through these stages easily (Aydogdu & Kesercioglu, 2005). According to Aydogdu and Kesercioglu, (2005); Arokoyu & Nna, (2012), these skills constitute a general definition of the logical and rational thought that an individual uses throughout his/her lifetime.

In order to explore these assertions, numerous science educators have being carrying out research consistently to determine the effect of SPSs on the academic achievement of senior secondary school students. Erkol and Ugulu (2013), conducted a study to determine biology teacher candidates, levels of scientific process skills and to compare the different variables. Scientific Method Abilities Test (SMAT) which has 36 multiple choice questions, was applied to 121 biology pre – service teachers enrolling in Necatibey Faculty of Education Balkesir, University. The result of the study showed that scientific process skills levels of pre – service biology teachers need to be developed and that there was no statistically significant difference between pre – service in terms of gender and age, except that there was for the class level. The result of the study was compared to other similar studies and it was regarded that science process skill levels biology student teachers' is in an intermediate level (with score 20 and 43) which is lower than other studies.

Furthetmore, Kanli and Yagbasan (2007) conducted another study to compare the effects of a laboratory based on the 7E learning cycle model with verification laboratory approach on university students' development of science process skills and conceptual achievement. In their study the sample consisted of 81 freshman university students who were taking the General Physics Laboratory-I- course at the university in Türkiye and the pre-test post-test design with control group was used. The night class students (43) who took lower weighted standard points from university entrance exam (UEE) than day class students were selected as experimental group. Day class students (38) were selected as control group. In order to assess hypotheses of study "Science Process Skills Test-SPST" was used and "Force Concept Inventory -FCI" to compare skills and conceptual achievement of control and experimental groups students. Both tools were given to both groups as pretest and posttest. Results of the analyses showed that there was a significant difference between the effect of verification laboratory approach and the laboratory approach based on 7E learning cycle model on development of students' science process skills and conceptual achievement. The findings of study suggested that laboratory approach based on 7E learning cycle model applications were more effective than the traditional verification laboratory approach applications to development of students' science process skills and remedy students, misconceptions about force and motion.

In another study where Chebii; Wachanga and Kiboss(2012), investigated the effectiveness of Science Process Skills Mastery Learning Approach (SPROSMALEA) on students' acquisition of Chemistry practical skills. The Solomon Four Group, Non-equivalent Control Group Design was employed in the study. The study was carried out in Koibatek District, Kenya where there has been persistent low achievement in the subject. 160 form two students from four co-educational schools, purposively selected from the district were taught the same course content on salts for a period of four weeks. The experimental group received their instructions through the use of SPROSMALEA approach and control using the conventional teaching methods. The researcher trained the teachers in the experimental groups on the technique of SPROSMALEA before the treatment. Science Process Skills Performance Test (SPSPT) and Classroom Observation Schedule (COS) were used for data collection. The results of the study indicated that students in the experimental groups outperformed the control groups in the acquisition of selected Chemistry practical skills. It was concluded that SPROSMALEA enhanced better performance in Chemistry than the conventional teaching method. Chemistry teachers should be encouraged to incorporate this method in teaching and should be included in regular in-service of teachers in Kenya.

Furthermore, a study (Akinbobola & Afolabi,2010) indicated high percentage rate of basic (lower order) science process skills (63%) as compared to the integrated

(higher order) science process skills (37%). The result also indicated that the number of basic process skills is significantly higher than the integrated process skills in West African senior secondary school certificate physics practical examinations in Nigeria across the years (1998- 2007). It was invariably recommended that, physics students at secondary schools level should be given the opportunity to handle and manipulate materials, tools and equipment in the laboratories; test their ideas experimentally; collect; compare; and interpret data; formulate models and draw conclusions. Reports by Arokoyu and Nna (2012) revealed that there is a significant difference in the mean observational and manipulative skills acquired by students of varying creativity and students performed better academically.

Another research carried out by (Igboegwu & Egbutu, 2011) on effects of cooperative learning strategy and demonstration method on acquisition of science process skills by chemistry students of different levels of scientific literacy recorded no significant interaction between teaching methods and scientific literacy levels of chemistry students on science process skills acquisition and recommended the use of cooperative learning strategy to enhance science process skills acquisition in chemistry students. While Gadzama (2012) in his study on the effects of science process skills approach on academic performance and attitude of integrated science students with varied abilities reported a significant difference on the academic achievement of experimental groups over control groups.

2.6 Gender and Academic Performance in Science

Gender has continued to be an inevitable difference among creatures particularly the human race. In a number of instances differences among males and females have been recorded and confirmed. In education, many differences have been documented between achievement of males and females. Many researchers and educationist feel that gender difference is one of the factors that affect academic performance (Okeke, 2001& Ukoh, 2013, Emmanuel, 2013). Gender difference has become a current issue locally, nationally and internationally. The concept "gender" refers to the amount of masculinity or femininity found in an individual. A normal man has a preponderance of masculinity while a normal female has a preponderance of femininity (Bichi, 2002). The influence of gender on students' performance has a long time been a concern to many educational researchers, but surprisingly no consistent results have been obtained (Adesoji & Babatunde, 2008; Muhammad, 2008; Ajaja & Eravwoke, 2010). According to Okeke (2008), sex refers to those characteristic of male or female which are biologically determined such as possession of penis by male and vagina by females. He maintained that, gender refers to the socially culturally constructed characteristics and roles which are ascribed to male and females in any society.

Gender is a major factor that influences career choice and subject interest of students. Okeke (2008) described the male attributes as bold, aggressive, tactful, economical use of words while the females are fearful, timid, gentle, dull, submissive and talkative. May be that is the reason Ezeudu and Theresa (2013), stated more difficulty works are usually reserved for males while the females are considered famine in a natural setting. Thus in schools males are more likely to take difficult subject areas like science (chemistry) while the females take to career that will not conflict with marriage chances, marriage responsibilities and motherhood (Muhammad, 2014). According to (Usman 2010) boys perform well in any rigorous work, while girls show to settle seated for less rigorous work and they perform better than boys in problem – solving type of activities. From other researchers, if boys and girls are given equal opportunities, they will perform equally well (Yoloye, 2004; Nworgun, 2005 & Usman, 2010).

Bichi (2006) reports that many studies in Singapore suggests that boys achieve better than girls in mathematics. While Lorchugh (2006), did not find either gender performing better. Okwo and Otubah (2007) in their studies on gender and cognitive styles found out that gender and cognitive styles are individually and jointly significant factors influencing students' achievement in physics essay test. It is often claimed that very few girls choose science in school and apart from biology very few of them are keen in science subject. International studies have confirmed such a view by showing that girls are more interested and perform better in biology than boys (Bello, 2001).According toMuhammad (2014) in her study on the influence of conceptual instructional method on students' performance and attitude towards practical chemistry among secondary school students found that there is no significant difference between male and female students academic achievement in the experimental group but for practical performance there was a significant difference between male and female students practical performance with male students performing better than their female counterparts. In short the notion of influence of gender on students' academic performance has continued to be an unending debate among educators. That is perhaps the reason why Usman (2010) maintained that the issue of gender in science teaching seems to be a controversy.

However, Muzumara (2007) maintained that equal opportunities for learning science should be given to both males and females. Teacher's ability to promote equal opportunities through their own personal behavior and attitudes, teaching styles and willingness to challenge discriminatory aspects and factors in the teaching can go a long way in helping to dominate gender inequity in science and technology. It is very important that all science teachers realize that they can help change gender differences in response to science education and that they need to take up this challenge to ensure that every child they teach gets the full benefit of science education. Both boys and girls must take active and leading roles in all practical science lessons. This will cultivate the interest in all students in class. All science teachers need to adopt this case, a gender-neutral approach in the lesson for the benefit of all learners.

2.7 Overview of Similar Studies

Olurukooba, (2001) conducted a research in Kaduna state of Nigeria on the relative effects of Cooperative Instructional Strategy and traditional method of instruction on academic achievement of students and their retention of chemistry concept and the attitude of male and female students towards Cooperative Instructional Strategy. The design of the research was quasi - experimental control group design. The population for the study was 1244 and a sample of 264;137 experimental subjects that were taught using Cooperative instructional method and 127 controls that were taught using the traditional lecture method. Three instruments; Chemistry Achievement Test (CAT), Attitude to Cooperative Instructional Strategy (ACIS) and Cooperative Instructional Package (CIP) were used for data collection. While T – test and Man – witney U – Test were used for dada analysis. The findings showed that the experimental group performed significantly better in the achievement test, than the control group. Based on the findings, the study strongly recommended the use of Cooperative instructional Strategy by secondary school teachers in teaching chemistry. However, the study was similar to the present study as both involved the effect of cooperative learning strategy on performance. The present study involves science process skills while the former involve attitude and retention.

Ajaja and Eravwoke, (2010) studied on how to adopt Cooperative Learning as an Instructional Strategy (IS) for teaching integrated science in order to influence students' achievement and attitudes towards studies in Abavo, Nigeria . Also investigated how moderating variables like sex and ability affect students' achievement in integrated science when CL is used as an IS. Their study employed a 2x2x2x2 factorial pre-test, post-test control group design consisting of cooperative group and traditional classroom teaching group. A sample of 120 students was randomly selected from 205 Junior Secondary class three (JS III) students in Abavo mixed secondary school, Nigeria. Scholarstic Ability Test in Integrated Science (SATIS), Students' Attitudes Scale (SAS) and Integrated Science Achievement Test (ISAT) were the instrument used and analysis of co-variance (ANCOVA) was used for analysis of data collected. One of the research hypotheses stated and tested at 0.05 level of significance was that, there is no significant difference in achievement test scores between students instructed with cooperative learning strategy and those taught using traditional classroom teaching method. The major findings of the research included a significant higher achievement test score of students in cooperative learning group than those in traditional learning group and strongly suggested the use of cooperative learning strategy by science teachers. The first research is similar to this study as both of them involve cooperative instructional strategy; the former research was carried out in Integrated Science while the present was in chemistry.

Olatoye, Aderogba and Aanu (2011), investigated the effect of cooperative and individualized teaching methods on senior secondary school students' achievement in organic chemistry in Ogun State, Nigeria. The research employed 3x2x2 randomized pre-test, post-test, quasi-experimental factorial design. The population comprised of all the public senior secondary schools in Ogun, Ogun State while the sample consisted of one hundred fifty six (156) students from which 26 boys and 26 girls were randomly selected each from three public schools for the study. The data was collected using Chemistry Achievement Test (CAT), Teaching Manual (TM) and Self – concept Questionnaire (SCQ) while the data was analysed using analysis of co-variance (ANCOVA). One of the hypotheses for the research was there is no significant main effect of treatment (cooperative, individualized and lecture) on students' achievement in organic chemistry.

Results revealed that there was significant main effect of treatment on students' achievement in chemistry. Both cooperative and individual method significantly improved students' achievement in organic chemistry though cooperative method is significantly better than individualized method. Also, the efficacy of the both teaching strategies has nothing to do with students' gender and self-concept. The present study differs slightly because it involved a variable which was Science Process Skills.

Igboegwu and Egbutu (2011), investigated the effect of cooperative learning strategy and demonstration teaching methods on acquisition of science process skills by chemistry students of different level of scientific literacy in Onitsa, Anambra State, Nigeria. The design of the study was quasi-experimental of pre-test post-test non-equivalent control group with a complete 145 SS II chemistry students drawn from six randomly selected schools in Onitsha, Anambra state, Nigeria from which 78 students were in experimental groups and while 67 students were in control groups. Some of the research questions and hypotheses include how teaching methods (cooperative learning strategy and demonstration method) affect acquisition of science process skills of senior secondary school year II chemistry students of different levels of scientific literacy?, there is no significant difference in the mean scores on the level of acquisition of science process skills of students of high, medium and low levels of scientific literacy taught chemistry concepts using cooperative learning strategy and those taught the same concepts using demonstration teaching methods. Data were collected using science process skills acquisition (SPSAT) and science literacy test (SLT). Mean and standard deviation were used to answer research questions while analysis of co-variance (ANCOVA) was used to test hypotheses at 0.05 level of significance. The results revealed that students taught using cooperative learning strategy performed better than those taught using demonstration method. Based on the findings, it was recommended that cooperative learning strategy should be used in teaching to enhance the acquisition of science process skills. The study is similar to this study in Cooperative Learning Strategy and acquisition of Science Process Skills and differs in Demonstration Teaching Method and level of Scientific Literacy.

Gambari, James and Olumorin (2013) conducted a study on the effect of cooperative, competitive and individualistic instructional strategies on the performance of high, medium and low academic achievers using video instructional package in Minna, Nigeria. Research questions were raised like what are the differences in the performance of students taught mathematics using Cooperative Video Instructional Package (COOVIP), Competitive Video Instructional Package (COMVIP) and Individualistic Video Instructional Package (IVIP) while one of the hypotheses formulated for the study was there is no significant difference in the performance of students taught mathematics using COOVIP, COMVIP and IVIP. A pretest, posttest, experimental control group design was employed for the study. A total sample of 120 senior secondary school mathematics students were randomly assigned into cooperative, competitive, individualistic and conventional teaching methods. Video instruction package (VIP) on mathematics and Geometry Achievement Test (GAT) were used for the collection of data. Analysis of variance (ANOVA) and Scheffe's test were used for data analysis. The findings indicated that there was significant difference in the performance of the groups in favour of cooperative learning strategy, CLS. Students' achievement levels had significant influence on the performance in competitive and individualistic instruction settings. They recommended that mathematics teachers should employ the use of CLS to improve students' performance to bridge the gap among high, medium and low achievers. However, Gambari et – al (2013) used Cooperative Based Video Instructional Package (CBVIP) while the present study used Cooperative Instructional Package (CIP).

In 2005, Fredrick Ssempala carried a research to determine gender differences in performance of chemistry practical skills among senior six students in Kampala district of S/Africa. The researcher raised questions for the study like what are chemistry practicals skills male and female students find most difficult to perform. Four research hypotheses were formulated to guide the study, one of which include there is no significant difference between male and female students in their ability to manipulate apparatus and equipment during chemistry practical. A cross sectional descriptive research design was used involving both qualitative and quantitative research strategies. The study participants were drawn from five mixed secondary schools in the district with a total of fifty (50) students participated, half of them girls and the other half boys. Chemistry practical test, student questionnaires and in depth interviews were used for data collection. Major finding of the research is that there was no significant difference between girls and boys in their ability to manipulate the apparatus/equipment, take observation, report/record results correctly, and compute/interprete/analyze results during chemistry practical. Based on the finding, it was recommended that students should be taught mole concept, volumetric analysis and ionic chemistry and balancing equation early enough so that girls and boys are able to compute/interpret/analyse results. However, the present study involved three variables; Cooperative Learning Strategy, Science Process Skills and gender while the former involved two variables; gender Performance and Chemistry Practical Skills.

A study was conducted by Temiz, Tasar and Tan (2006) to measure the development of 12 science process skills in Gazi, Turkey. A sequential-recursive way was followed to develop summative science process skills instrument. A 15 constructed response (CR) questionnaire and one hands-on task was developed. In its final form it was administered to a total of 80 grade 9 students in four different high schools in

Metropolitan Ankara, Turkey. A Multiple Format Test in Science Process Skills (MFT – SPS) was used for data collection while the statistical tools used to analysed the data collected were mean, standard deviation and analysis of variance (ANOVA). The result showed that there are no statistically significant differences between the students in different schools in the skills of observing, classifying, and inferring; however, the differences are statistically significant on skills involving measurement, using number-space relationships, predicting and recording data. This suggested that a multiple format instrument that include both hands-on task and paper and pencil items could be successfully developed and used. The study under review is related to the present study in that, it focuses on developing test format for science process skills while the present study investigated the effect of cooperative learning strategy on acquisition of science process skills.

Atkamis and Ergin (2008), investigated the effects of teaching scientific process skills education to students to promote their scientific creativity, attitude towards science and achievement in science in Turkey. The pre-test post-test experimental model with control group was used in the research. The sample of the study was 40 students of 7th grade of elementary school in Buca, Turkey. Major question raised by the researchers was that, is there any significant difference between the academic achievements of the students who got and did not get the science process skills training according to their pre-test and post-test results? Instruments used for the collection of data were combination of force and motion - the energy" chapter achievement scale, the science attitude scale, the scientific creativity scale. The data were analysed using mean, standard deviation, independent samples t-test, and paired sample t-test by SPSS 11.0 statistical program. It was determined in the study that the scientific process skills education increased the students' achievement and scientific creativities; however, no meaningful progress was made on the attitude towards science when compared to the teacher-centred method. This study under review is related to the present study in that, it focuses on finding out the impact of science process skills on scientific creativity, attitudes towards science and achievement in science while the present study investigated the effect of cooperative learning strategy on academic performance and acquisition of science process skills.

Gadzama (2012), determined the effect of science process skill approach on academic performance and attitude of integrated science students with varied abilities in Potiskum, Yobe State, Nigeria. The pre-test post-test quasi experimental and control group design was used for the study. A sample of 504 students randomly selected by balloting from four co-educational schools in Potiskum Educational Zone was used. Four research questions were raised, one of which was, what are the differences in the mean scores of the subjects in the high, average and low ability sub-groups taught Integrated Science using Science Process skills approach and their counterparts taught usinglecture method? One among four hypotheses formulated said that, there is no significant difference in the mean scores of subjects in the high, average and low ability sub-groups taught Integrated Science using Science Process Skills Approach and their counterparts taught using lecture method. Test of Practical Skills (TOPS), Integrated Science Achievement Test (ISAT) and Attitude of Students towards Integrated Science Questionnaires (ATISQ) were used to collect data while data collected were analysed using analysis of variance (ANOVA), Kruskall Wallis and Man – witney U - Test. The results of the study found that, there was significant difference in the mean academic achievement scores of the experimental high, average and low ability levels, followed by control group average, high and low. While on gender, no difference was recorded. This research under review is related to the present study in that, it focuses in determining the effect of science process skills on academic performance and attitude of integrated science students of varied ability towards integrated science while the present study investigated the effect of cooperative learning strategy on the acquisition of science process skills and academic performance of chemistry students.

The researchers outlined above did not do much on the impact of Cooperative Learning Strategy (CLS) on Science Process Skills acquisition (SPSs) and students' academic performance. Therefore, the objective of this study was to investigate the impact of CLS on SPSs acquisition as well as academic performance of Senior Secondary Chemistry Students.

2.8 Implication of the Literature Reviewed for the Present Study

Literature reviewed from studies in the area of cooperative learning strategy, science process skills and academic performance as well as gender differences has been undertaken. The review was on the previous works done pertaining to the problems students have with learning chemistry concepts. The literatures reviewed indicated that lecture method of teaching which is being used predominantly by science teachers for instruction, is one of the major causes for students' poor performance in science class. Several researches have been conducted on the use of Cooperative Learning Strategy (CLS) to aid students learn chemistry concepts and improve their performance. Other literatureshave also indicated the impact of Science Process Skills (SPSs) on students' academic performance in chemistry.

From the literature reviewed it was recorded that, effective methods of instruction such as cooperative learning strategy improves students' performance in different angles.Till date, the problems associated with learning chemistry persist, that is why the researcher deemed it necessary to use cooperative learning strategy to help students in their academic performance. However, most of the research works used for the literature review was carried out at national and international levels and in different subject like mathematics, biology and integrated science, while the present study was in chemistry. It was also showed that, students'results based on gender have not been consistent. Research work on the use of cooperative learning strategy to improve acquisition of science process skills and academic performance is very scanty. Most researches were separately done either on the use of Cooperative Learning Strategy to enhance students' performance or the use Science Process Skills to enhance students' performance as showed from reviewed literatures. The use of Cooperative Learning Strategy (CLS) on Science Process Skills acquisition (SPS) is relatively new more especially in the field of chemistry at Senior Secondary School. This signified the need to carry out research on the use of cooperative learning strategy on the acquisition of science process skills and academic performance in chemistry. This study therefore, was indebted to fill this gap by investigating the impact of Cooperative Learning Strategy on Science Process Skills acquisition.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This study investigated the impact of cooperative learning strategy on the acquisition of science process skills and academic performance among chemistry students at secondary schools in Zaria Educational Zone. The chapter deals with methodology for the study and is presented under the following sub – headings:

3.2 Research Design

3.3 Population of the Study

3.4 Sample and Sampling Technique

3.5 Instrumentation

3.5.1 Validation of the Instruments

3.5.2 Pilot Testing of the Instruments

3.5.3 Reliability of the Instruments

3.5.4 Items Analysis

3.6 Administration of the Treatment

3.6.1 Description of Jigsaw I Cooperative Learning Model

3.6.2 Administration of the Treatment

3.6.3 Teaching the Control Group

3.7 Data Collection Procedure

3.8 Procedure for Data Analysis

3.8.1 Research Questions

3.8.2 Research Hypotheses

3.2 Research Design

A pretest, posttest, quasi-experimental control groups design using intact classes which did not allow randomization of the subjects (Sambo, 2005) was employed for this study. Two groups of students were used for data collection i.e the Experimental and Control groups. A pretest (O_1) was administered to the two groups in order to determine the equivalence of the groups in ability before the commencement of the treatment. Treatment (X_1) was given to the experimental group i.e. students were taught chemical equilibrium concepts using the Jigsaw model cooperative learning strategy for six weeks. The control group (X_0) was taught the same chemical equilibrium concepts using the lecture method for six weeks. At the end of the treatment period, a posttest (O_2) was administered to both groups of students in order to evaluate the effectiveness of the treatment in enhancing the learning of chemical equilibrium concepts among SS II students. The research design is represented in Figure 3.1

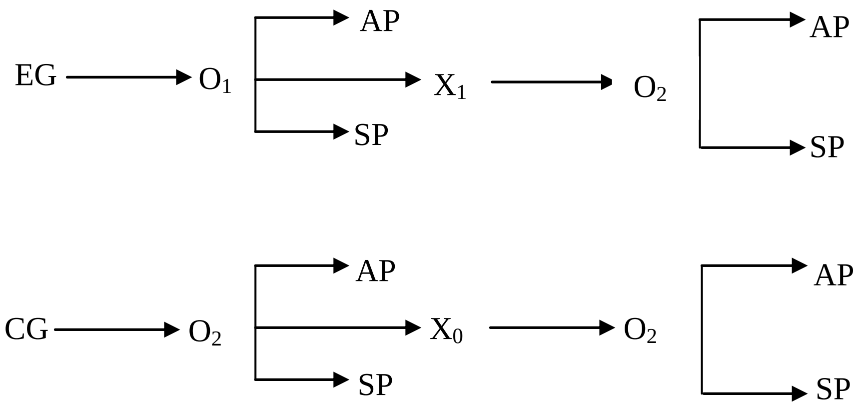


Figure 3.1: Research Design

Where:

EG = Experimental Group

CG = Control Group

O_1 = pretest

X_1 = Cooperative Learning Strategy

X_0 = lecture method

AP = Academic Performance

SP = Science Process Skills

O_2 = posttest

This design has the following advantages (Bichi, 2002).

1. It was used to statistically find out any difference between the groups at the beginning of the study from the results of the pretest i.e to compare the equivalence of the two groups academically.
2. It was used to give indication of gain in understanding of selected test due to application of the treatment.
3. It could also give an indication of the skills gain by students after instruction.
4. The mean scores of the two groups were calculated. Therefore it was assumed that any difference in the performance of the groups can only be attributed to the treatment given, since the treatment administered was the major difference.

3.3 Population of the Study

The population of the study comprised of one thousand seven hundred and fourty three (1743) SSII science students in the public senior secondary schools underZaria Education Zone of Kaduna State. The population comprised of four boys schools, six girls schools and ten co-educational schools consisting of 380 males and 290 females. Table 3.1 shows the population distribution for the study.

Table 3.1: Population of the Study

S/N	School	No. of SSII Students		Total
		M	**F**	
1	GSS Zaria	100	00	100
2	GSS TudunJukun	100	60	160
3	GSS Magajiya	30	38	68
4	Barewa College Zaria	130	00	130
5	GGSS D/Bauchi	00	173	173
6	GGSS Zaria	00	48	48
7	GSS Aminu	33	37	70
8	GSS Gyallesu	48	39	87
9	GGSS K/Gayan	00	100	100
10	GGSS Pada	00	80	80
11	GSS Kaura	170	00	170
12	GSS Chindit Barracks	92	00	92
13	GSS Dakace	30	26	56
14	GSS T/Saibu	30	19	49
15	GSS Kugu	06	04	10
16	GGSSChindit Barracks	00	60	60
17	GSS Muchia	38	22	60
18	GSS Likoro	20	15	35
19	AlhudahudaCollege Zaria	00	120	120
20	GSS K/Kuyanbana	45	30	75
Total		872	871	**1743**

Source: (Kaduna State Ministry of Education, 2016).

3.4 Sample and Sampling Technique

Since gender was one of the variables in this research, only co – educational schools were used. Eleven schools in the population were co – educational comprising of 670 students out of which 380 were males and 290 females. Two schools that did not differ significantly in performance were chosen and assigned as experimental and control groups. The names of all the co-education schools in the population were written on separate pieces of papers and the papers were put in a container. Four schools were drawn-out one at a time from the container using simple balloting method. The four schools were given the research instruments (CPT & TOSPS) to answer in 1 hour each at separate time. The results of the test were analysed using Analysis of Variance (ANOVA) to choose two schools that are equivalent in performance. The results of ANOVA test showed no significant difference between the schools. Therefore two schools were selected which were later assigned into experimental and control groups by means of throwing a coin. The schools were: experimental group (A) and control group (B), with the total number of 162 students as sample size from which 93 were males while 69 were females. The choice of sample from the selected schools was guided by central limit theory which recommended a minimum of 30 subjects as sample for experimental research (Tuckman, 1999; Sambo, 2005). Table 3.2 shows the sample for the study.

Table 3.2: Sample for the Study

Schools	**Groups**	**Sample of Students**		**Total**
		Males	**Females**	
A	Experimental	48	39	**87**
B	Control	45	30	**75**
Total		93	69	**162**

3.5 Instrumentation

The following instruments were used by the researcher for data collection.

(i) Chemistry Performance Test (CPT) developed by the researcher

(ii) Test of Science Process Skills (TOSPS) adapted from (Gumel,2007)

Selection of Topics Taught

The following topics in Chemical equilibrium and reversible reactions were taught to the subject of the study.

i. Reversible reactions and chemical equilibrium

ii. Law of mass action and equilibrium constant

iii. Le-chatelier’s principle and effect of change in concentration on equilibrium

iv. Effect of change in pressure on the system in equilibrium

v. Effect of change in temperature on the system in equilibrium

vi. Ionic equilibria

These topics were been selected because they are part of SS II syllabus. Also chemical equilibrium and reversible reactions have been used for the study because they have been identified to be contributing to students' poor performances (Gongden, Gongden & Lohdip, 2011; Emmanuel, 2013). Also the concepts served as the basis for understanding of some chemical processes used in industries and companies. The table of items specification based on the topics taught is presented in Table 3.5

Chemistry Performance Test (CPT)

Chemistry Performance Test (CPT) was designed by the researcher to measure academic performance of students in chemical equilibrium before and after treatment. This instrument consists of 40 objective test items; 20 multiple choice items, 10fill in the blank spaces and 10 true or false type items. Each item attracted 1 mark when answered correctly making 40 marks (See Appendix I). The table of specification for CPT based on Blooms taxonomy is presented in Table 3.3.

Table 3.3: Items Specification for CPT Based on Blooms Taxonomy of Cognitive Domain

S/N	Concepts	Kno	Com	Apl	Anl	Syn	Eva	Total	%
1.	Reversible reactions/Chemical equilibrium	2,3	26	1	29	24	12	7	2.8
2.	Law of mass action/Equilibrium Constant	22	23	4	32	27	16	6	2.4
3.	Le-chatelier's principle/Concentration	30	37	5	11	20	35	6	2.4
4.	Effect of change in pressure on equilibrium	7	31	8	25	36	33	6	2.4
5.	Effect of change in Temperature	21	9	17	34	6,28	13	7	2.8
6.	Ionic Equilibria	19	14,18	15,38	10	39	40	8	3.2
	TOTAL							40	**100**

Source: Bloom, (1964)

Test of Science Process Skills (TOSPS)

This test (TOSPS) was adapted from (Gumel, 2007) with little modifications and was designed to measure Science Process Skill Acquisition among SS II Chemistry students. The test consists of 25 multiple choice items designed to measure five skills. The five skills were observation, measurement, inference, interpretation and hypothesis. Five questions were set for each skill making a total of 25 items in the instrument. Each item when answered correctly attracts one mark. Thus the total number of marks for this instrument is 25. The summary of the items in the instrument (i.e TOSPS) and the specific skill each item set to measure is shown in Table 3.4.

Table 3.4: Summary of Items in TOSPS

Item	Skills	Number
1 - 5	Observation	5
6 - 10	Measuring	5
11 - 15	Inferring	5
16 - 20	Interpreting	5
21 - 25	Hypothesising	5
TOTAL		25

All the items used in this test were constructed using the multiple choice format (see Appendix II). Also these skills were selected for use in the instrument, TOSPS because they are appropriate to the topics of the study.

3.5.1 Validation of the Instruments

The two instruments were submitted to three experts: Ph.D holders and Senior lecturers from department of Chemistry and Department of Science Education, ABU, Zaria. The experts were asked to critically examine and assess all the items in the instruments paying attention to the following whether:

(i) the test items can test what they are meant to examine.

(ii) the questions adequately cover the concepts chosen

(iii) the language expression used is simple, clear, precise and free from ambiguity.

(iv) the questions conform with ability level of the students

The experts made constructive criticisms in the language construction and content of the instrument. The corrections were made leading to the final selection of the items and the respective marking scheme as contained in Appendix I & II. For example, in the case of Chemistry Performance Test (CPT), some items were corrected and modified. Item 6 initially reads as:

In the equilibrium reaction,A C+D, more of C and D are produced when temperature is increased. Which of the following statement is a correct deduction?

a. is exothermic in the forward direction.
b. is endothermic in the forward direction
c. does not require catalyst
d. has low activation energy.

This was modified to:

In the equilibrium reaction, A $\rightleftharpoons$ C+D, more of C and D are produced when temperature is increased. Which of the following statement is a correct deduction?

a. the reaction is exothermic in the forward direction.
b. the reaction is endothermic in the forward direction
c. the reaction does not require catalyst
d. the reaction has low activation energy

Item 10 reads as:

Consider the equilibrium system represented by the following equation:

$Cu^{2+}_{(aq)} + 4NH_{3(aq)} \rightleftharpoons [Cu(NH_3)]^{2+}$

(light blue) (deep blue)

It infers that, the deep blue colour will fade on adding

a. Cu_2^{+}(aq)
b. H_2SO_4(aq)
c. NH_3(aq)
d. NaCl(aq)

This was modified to:

Consider the equilibrium system represented by the following equation:

$Cu^{2+}_{(aq)} + 4NH_{3(aq)} \rightleftharpoons [Cu(NH_3)]^{2+}_{(aq)}$

(light blue) (deep blue)

It infers that, the deep blue colour will fade on adding

a. $Cu_2{}^{+}{}_{(aq)}$

b. $H_2SO_{4(aq)}$

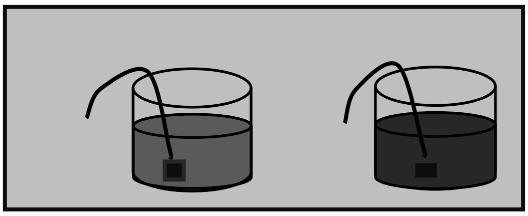
c. $NH_{3(aq)}$

d. $NaCl_{(aq)}$

While in the case of Test of Science Process Skills (TOSPS)

Item 10 reads as:

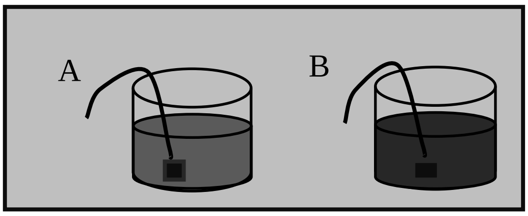
A teabag was placed in each glass of water for two minutes, why is that the tea in glass 2 is darker than the tea in glass 1?



a. There is more water in glass 1
b. Glass one is larger than glass 2
c. The water in glass two (2 s higher than the water temperature in glass 1.

This was modified to:

A teabag was placed in each of glasses A & B of water for two minutes, why is that the tea in glass B is darker than the tea in glass A?



a. There is more water in glass A
b. Glass one is larger than glass B
c. The water temperature in glass Bis higher than the water temperature in glass A.
d. There is less water in glass B.

The items after effecting corrections were used appropriately for collecting the data used for the study.

3.5.2 Pilot Testing

The instruments outlined were pilot tested using SS II students in the Senior Secondary Schools in Zaria Education Zone. The Chemistry Performance Test (CPT) and

Test of Science Process Skills (TOSPS) were administered to 30 SS II chemistry students who were selected randomly from GSS Tudun Jukun, Zaria.

The purpose of the pilot study according to Bichi (2002) and Muhammad (2014) was to:

a) determine the reliability coefficient of the instrument before administration.

b) assess the feasibility of the study before trial.

c) identify possible problems or difficulties that respondents may encounter with a view to eliminate them.

d) determine the approximate time duration which the subjects would need to answer the test items properly. The appropriateness of the instrument in terms of clearity of the items and the reliability of the test items was determined. Also the discriminative indices and difficulty indices was determined using the students' scores from the pilot study.

3.5.3 Reliability of the Instruments

The degree of error or precision in measuring an estimate of a test is called its reliability (Bichi, 2002 & Muhammad, 2014). A test is said to be reliable if repeated measurements using the test gives more or less the same results. Using the data that was obtained from the pilot study, the reliability coefficients of the instruments (CPT & TOSPS) were calculated by employing test-retest method. The test was administered to SS II Chemistry Students of GSS Tudun Jukun, Zaria which was not part of the sample. The instruments were administered twice with the interval of two weeks as proposed by Tuckman, (1975) and Sambo,(2005). Pearson Product- Moment Correlation Coefficient Statistics was used for the analysis. The reliability coefficient of Chemistry Performance Test (CPT) was found to be $r = 0.88$, which shows that the reliability of the instrument is high and was used for data collection for the study. The reliability coefficient of Test of

Science Process Skills (TOSPS) adapted from Gumel,(2007) was r = 0.6 while the reliability coefficient of Test of Science Process Skills (TOSPS) for this study was found to be r = 0.79, which showed that the reliability of the instrument was high and was used for data collection for the study.

3.5.4 Items Analysis of the Instruments

Item analysis was carried out on the results of the Chemistry Performance Test (CPT) and Test of Science Process Skills (TOSPS) to determine the facility indices (FI) and discrimination indices (D.I) of the instruments, from the data collected in the pilot testing. They were derived as follows:

Facility Index (F.I) of the Instruments

Facility index otherwise called difficulty index is the percentage of students who obtain the correct answer on an item. For computing the difficulty index for each item, the steps are as follows:

- The scores on the whole test scripts would be ranked in the order from highest to lowest.
- One third of the scores of the high scoring students and one third of the scores of the bottom scoring students would be selected.
- The percentage of the high scoring one third and the low scoring one third of the total test items would be calculated.
- The items difficulty index will be computed by adding the percentage of those that got the items correct in the bottom scoring and high scoring groups and then divide by two, The formula is;

$$P = \frac{RU + RL}{N}$$

Where:

P = item difficulty

RU = number of students that got the item right in upper one third percent.

RL = number of students that got the item right in bottom one third percent.

N = number of students involved in the analysis (not the entire students that sat for the test).

According to Tristan (1999) and facility indices between 0.30 – 0.70 are recommended for selecting good items for performance test. For this study, items which fall between the range of 0.30 – 0.70 were finally selected.

Discrimination Index (D.I):

Discrimination indices of a test refer to the capacity of such a test to discriminate or distinguish between high and low achiever among students in the sample. If an item has positive discrimination, it implies that a large proportion of the more competent students than poor ones got the item right. If the value is zero, the item has zero discrimination, which means that the items are unable to distinguish between the competent and incompetent students. The negative value of discrimination index indicates that more of the low achievers got the item right compared to the more competent ones. Mehrens and Lehmann (1984) stressed that the higher the discrimination indices the better, recognizing that there are situations where low discrimination indices is to be expected. e.g. classroom test. Frust, (1958) stated that discrimination indices which range from 0.30 to 0.70 are described as moderately positive and above this are highly positive. The discrimination index was calculated using the givenformula by (Frust,1958; Olorukooba, 2001 & Muhammad, 2014).

$$D.I = \frac{RU - RL}{\frac{1}{2}N}$$

Where:

D.I = discrimination index

RU = number of upper 27% of respondents

RL = number of lower 27% of respondents

N = total number of respondents

Tristan (1999), Field (2006) and Sambo (2005) recommended discrimination indices between 0.30 – 0.70 for selecting good items for performance test. For this study, items which fall between the range of 0.30 – 0.70 were finally selected. Items with discrimination indices between 0.0 – 0.29 were difficult were rejected, while those between 0.30 – 0.70 were moderately positive and were selected, and those with discrimination indices above 0.70 and above were highly positive and were rejected. For this study, items with discrimination indices between 0.30 – 0.70 were selected and those with very low indices were discarded and some reconstructed and finally selected. This is in line with Sambo, (2005) and Field, (2006). See Appendix VII & VIII.

3.6 Administration of the Treatment

3.6.1 Description of Jigsaw I Cooperative Learning Model

Jigsaw I is a cooperative learning model applicable to team assignments that call for expertise in several distinct areas (Olorukooba, 2001; Abdullahi, 2014). For example, in a laboratory exercise, areas of expertise might include experimental design, equipment calibration and operation, data analysis, and interpretation of results in light of theory, and in a design project the areas might be conceptual design, process instrumentation and control. The concept of chemical equilibrium was broken into sections/parts. The students were divided into teams of five or six; the team members were designated to be responsible for each section. To begin the lesson, the teacher gave group names written on a card. Each individual member of the group was then given specific task to work/study. His/her expert name attached to the study note of the task given to him/her was provided to him/her. Then all the experts in each area were given specialized training, which involved getting handouts, presentations by the course teacher on the area in question and each expert was asked to study his/her task for some time. The students in the same group studying the same task from each group who were not allowed to see the task given to his/her fellow group members were asked to form expert groups. The expert groups studied collectively the task and recorded useful information on the worksheet earlier provided for the purpose of feedback to his/her main group. Members of the expert groups were after sometimes asked to break and go back to their main groups, called home groups where each expert explained his/her task to the remaining members of his/her group. Other members of the group were encouraged to ask questions and clarifications from the experts. As the group discussion was on, members of each group were assigned to perform certain roles like the time keeper, questioner, reader, reminder etc.

3.6.2 Administration of the Treatment

Teaching the subjects in the experimental group was conducted by the researcher using the Jigsaw I model of cooperative Learning strategy. This was to enable the researcher to effectively handle the experimental group following all the necessary criteria for the adoption of the model. In this model, students were assigned into groups to work on academic material that has been broken down into sections. The teacher introduced the lesson to the students and explained to them what they are expected to do. For example, the concept of chemical equilibrium was broken down into meaning of reversible reactions, equilibrium, examples and characteristics. Each team member was asked to read his/her section. Next, members of different teams who had studied the same sections met in expert groups and discussed the sections. Then the students returned to their teams and took turns teaching their teammates about the concept they learned at the expert group. Finally each member was asked to fill in his/her work sheet paper and submit for assessment, (See Appendix III, V & VI). In order to produce appropriate treatment, the experimental group was taught for a period of six weeks with one hour thirty minutes for each lesson. Flow - chart of the strategy is presented in Figure 3.2.

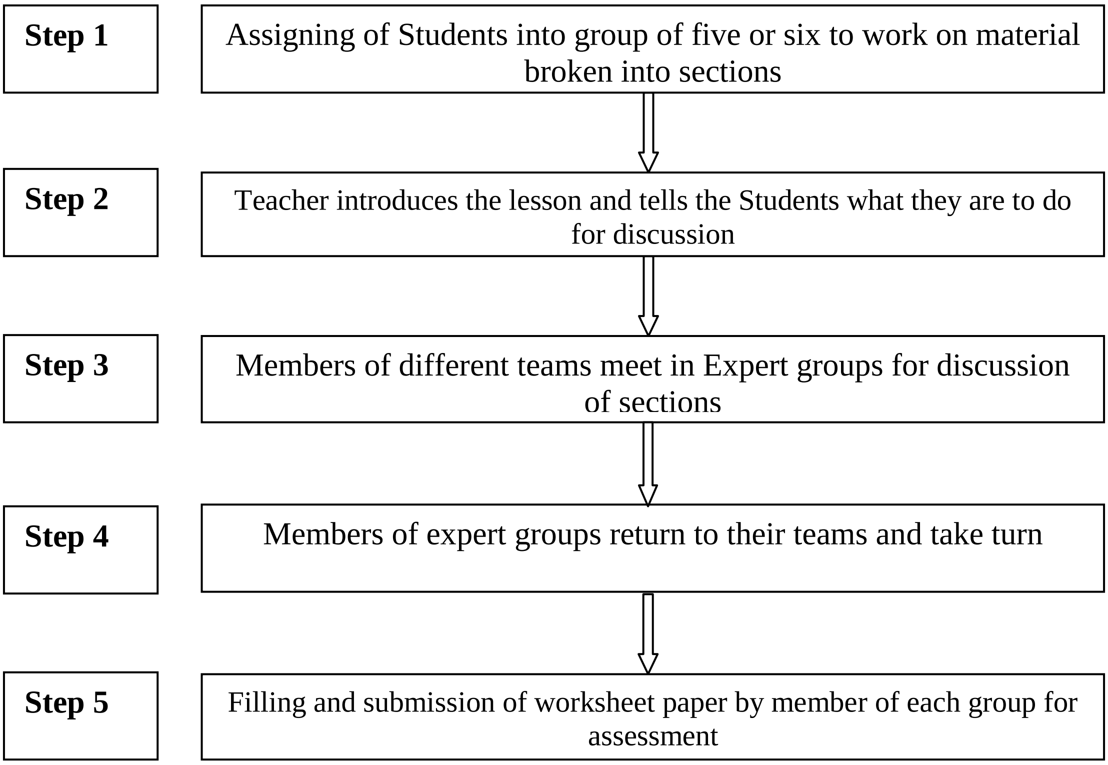


Figure 3.2: Flow - chart for the Jigsaw Cooperative Learning Model adapted from Elliot, (1978).

Step 1: Students were assigned into groups to work on academic material that has been broken down into sections.

Step 2: The teacher introduced the lesson to the students and explained to them what they are expected to do; example students were asked to read some sections of the topic to be studied.

Step 3: Members of different teams who had studied the same sections met in expert groups and discussed the sections

Step 4: Students returned to their teams and took turn teaching their sections to the team members.

Step 5: Each member was asked tp fill his/her work sheet paper and submit for assessment.

The flow - chart of Jigsaw Cooperative Learning Strategy was presented in fig 3.4.The detail of the lesson plan for the experimental group was presented in Appendix III.

3.6.3 Teaching the Control Group

The control group was taught the same concepts by the researcher using the lecture methods for the periods of six weeks. The note of the lessons prepared by the researcher was strictly adhered to in the teaching of the subjects in the control group. The concepts was discussed and explained verbally using talk and chalk method; students wrote notes where necessary and asked questions where they found any difficult concept to understand. The details of the lesson plan for the control group are shown in Appendix IV.

3.7 Data Collection Procedure

After receiving letter of introduction from the director, Zaria Education Zone, the researcher proceeded to the schools; experimental and control groups for conduct of the activities of the study which lasted for six weeks.Immediately after six weeks period of the treatment, a post test was administered to both the subjects in the experimental and control groups with the CPT and TOSPS separately. The administration of CPT lasted for 1 hour 30 minutes in which a copy of the instrument and structured answer sheet was given to each student in both the subjects in the experimental and control groups. While TOSPS lasted for 1 hour where a copy of the instrument and structured answer sheet was given to each student in both the subjects in the experimental and control groups. The CPT and TOSPS were scored by the researcher using carefully prepared and validated marking scheme to ensure uniformity in scoring the students. The research instruments were personally administered by the researcher after which the results were subjected to data analysis.

3.8 Procedure for Data Analysis

The results and responses of the subjects obtained from the two instruments were scored using the marking guide for each instrument respectively, and the data collected was analyzed by re-stating the research questions and null hypotheses, while appropriate statistical tools were used for testing the stated null hypotheses at $P \leq 0.05$ level of significance.

3.8.1 Research Questions

The stated research questions for this study were analysed using mean and standard deviation.

3.8.2 Research Hypotheses

The following research hypotheses were formulated for testing at $p \leq 0.05$

H_{O1}: There is no significant difference in science process skills acquisition between SS II chemistry taught using cooperative learning strategy and those taught using lecture method.

This hypothesis was tested using t – test statistic.

H_{O2}: There is no significant difference between the academic performance mean scores of SS II chemistry students taught using cooperative learning strategy and those taught using lecture method.

This hypothesis was tested using t – test statistic.

H_{O3}: There is no significant difference in science process skills acquisition between male and female SS II chemistry students when exposed to cooperative learning strategy.

This hypothesis was tested using t – test statistic.

H_{O4}: There is no significant difference between the academic performance mean scores of male and female SS II chemistry students taught using cooperative learning strategy.

This hypothesis was tested using t – test statistic.

CHAPTER FOUR

DATA ANALYSIS, RESULTS AND DISCUSSION

4.1 Introduction

The aim of the study was to investigate the impact of cooperative learning strategy on the acquisition of science process skills and academic performance in chemistry among secondary school students in Zaria Education Zone. This chapter contains the description of data analysis, results, summary of findings and discussion. The data for the study were generated using two instruments: Test of Science Process Skills (TOSPS) and Chemistry Performance Test (CPT). The data were analysed using the Statistical Package for Social Sciences (SPSS).

The level of significance adopted for the study was 0.05. This level of significance forms the basis for retaining or rejecting the null hypotheses.

4.2 Data Analysis and Result Presentation

Two instruments; Test of Science Process Skills (TOSPS) and Chemistry Performance Test (CPT) were used to collect students' Test of Science Process Skills scores and Chemistry Performance Test scores for analysis. In this study, four research questions along with corresponding hypotheses were formulated for answering. The research questions were presented as follows:

Research Question One: What would be the difference (if any) in science process skills acquisition between SS II students taught chemistry using cooperative learning strategy (CLS) and those taught using lecture method?

To determine the difference in science process skills acquisition, the scores of the Students who were exposed to CLS and those who were taught with lecture method were computed and compared using mean and standard deviation. Table 4.1 shows the computed mean scores along with their standard deviation and standard errors of the scores of the two groups after (post-test) the treatment.

Table 4.1: Mean Scores in TOSPS of the Experimental and Control Groups

Stages	Group	N	Mean	Std. Dev.	Std. Error	Mean diff.
Posttest	Experimental	87	12.99	2.026	.217	5.99
	Control	75	7.00	2.885	.333	

From the results in Table 4.1 showed that after the treatment (Post-test), the students who were exposed to Cooperative Learning Strategy (CLS) had mean score of 12.99 while students in the control had a mean score of 7.00. The mean difference in favour of the experimental group was 5.99 as indicated in Table 4.1. This shows that, the performance mean scores of students in the experimental group was higher when compared with their counterparts who were taught with lecture method. The mean difference of 5.99 has indicated that there was difference in the mean science process acquisition skills between subjects in control and experimental groups in favour of the experimental group. However, the test of significance of the observed variability was conducted by testing null hypothesis one.

Research Question Two: What is the difference (if any) between the performance meanscores of SS II students taught chemistry using Cooperative Learning Strategy and those taught with lecture method?

The difference in performance mean scores between experimental and control groups were determined by computing the performances of the students after the treatment (posttest) and comparing them using mean and standard deviation as summarized in Table 4.2.

Table 4.2: Mean and Standard Deviation Scores in CPT of the Experimental and Control Groups

Stages	Group	N	Mean	Std. Dev.	Std. Error	Mean diff.
Posttest	Experimental	87	18.59	5.141	.551	6.96
	Control	75	11.63	3.271	.378	

Table 4.2 showed that the difference between students who were exposed to Cooperative Learning Strategy and those taught with lecture method after the treatment, was 6.96 with performance of students in the experimental group having a mean score of 18.59 while those of the control group taught with lecture method had a mean score of 11.63. This observation clearly shows that Cooperative Learning Strategy has a positive impact in improving the academic performance of students in chemistry. This observed variability in the mean academic performances was subjected to a test of significance by testing null hypothesis two.

Research Question Three: What would be the difference (if any) in science process skills acquisition between SS II male and female students taught chemistry using Cooperative Learning Strategy?

The objective here was to examine the differences in the science process skills performance between male and female students who were exposed to Cooperative Learning Strategy. To determine the difference on the students' science process skill acquisition, the scores of the male and female students after the exposure were computed using mean and standard deviation and presented in Table 4.3

Table 4.3: Mean and Standard Deviation Scores in TOSPS between Male and Female Students in the Experimental Group

Stages	Gender	N	Mean	Std. Dev.	Std. Error	Mean diff.
Posttest	Male	48	12.79	2.123	.306	0.44
	Female	39	13.23	1.898	.304	

In Table 4.3, it was indicated that theperformances mean scores of the male and female students after their exposure to the Cooperative Learning Strategy, rose correspondingly with a mean difference of0.44 in favour of the female students. The mean difference was small. The observation here implies that the students' gender may not play a major role in their science process skills acquisition when exposed to CLS. This observation was subjected to test of significance by testing null hypothesis three.

Research Question Four: What is the difference in academic performance of SS II male and female students taught chemistry using cooperative learning strategy and those taught with lecture method?

The aim here was to examine possible differences in the performance of male and female students who were taught chemistry with Cooperative Learning Strategy. In providing answer to this question, the chemistry performance scores of the male and female students after the treatment were computed using mean and standard deviation and presented in Table 4.4.

Table 4.4: Mean and Standard Deviation Scores in CPT between Male and Female Students in the Experimental Group

Stages	Gender	N	Mean	Std. Dev.	Std. Error	Mean diff.
Posttest	Male	48	18.25	5.004	.722	0.75
	Female	39	19.00	5.341	.855	

Table 4.4, revealed that after exposure to Cooperative Learning Strategy, the mean difference in the performanceof male and female students was 0.75 in favour of the female students. The mean scores for the male students was 18.25 after their exposure to Cooperative Learning Strategy while that of the female students was 19.00 respectively. This is an indication that Cooperative Learning Strategy enhanced the performance of the students irrespective of their gender and the mean difference, 0.75 shows that there is difference in academic performance between male and female students in the

experimental group. This observation was subjected to test of significance by testing null hypothesis four.

4.3 Hypotheses Testing

Four corresponding null hypotheses were formulated for testing in this study. The statistical tools used for testing these hypotheses were t-test statistic.

Null Hypothesis One: There is no significant difference in science process skills acquisition between SS II chemistry students taught using cooperative learning strategy and those taught using lecture method.

The science process skills test for the students exposed to the use of Cooperative Learning Strategy and those taught using lecture method were compared to determine the effect of the treatment of the CLS. The two sample t-test was used to compare the performances of the two groups after the treatment. The result is presented in Tables 4.5.

Table 4.5: Result of t-test Analysis Posttest Scores in TOSPS between Experimental and Control Groups

Test	Group	N	Mean	Std. Dev.	Std. Err.	t-obs	Df	P-value	Remarks
Posttest	Experimental	87	12.99	2.026	.217	15.444	160	.00	S*
	Control	75	7.00	2.885	.333				

(Df = 160, P < 0.05, S* = Significant)

The result in Table 4.5 showed that after the treatment, significant difference in the science process skills acquisition was observed as indicated with a t-value of 15.44 for the posttest score obtained at 160 degree of freedom. The observed level of significance for the test was 0.00 ($P < 0.05$). These are clear indication that the two groups were significantly different in their science process skills acquisition after the exposure of the experimental group to cooperative learning strategy. By these observations, the null hypothesis which states that there is no significant difference in science process skills acquisition between SS II chemistry students taught using cooperative learning strategy and those taught using lecture method is therefore rejected.

Null Hypothesis Two: There is no significant difference between the academic performances mean scores of SS II chemistry students taught using cooperative learning strategy and those taught using lecture method.

The performance in chemistry of students exposed to cooperative learning strategy and those taught using lecture method (control group) were compared to determine the significance of the variability obtained in Table 4.2 where their chemistry performance test was compared. The two sample t-test was used to compare the performances of the two groups after the treatment. The result is presented in Table 4.6 for post-test.

Table 4.6: Result of t-test Analysis of Posttest Mean Scores of Experimental and Control Groups on CPT.

Test	Group	N	Mean	Std. Dev.	Std. Err.	t-obs	Df	P-value	Remarks
Posttest	Experimental	87	18.59	5.141	.551	10.092	160	.00	S*
	Control	75	11.63	3.271	.378				

(Df = 160, P < 0.05, S* = Significant)

The result in Table 4.6 showed that for the post test scores after the exposure of the experimental group to cooperative learning strategy, the observed t-value (10.092) was higher than the critical value of 1.96 and the level of significance for the test was 0.00 ($P < 0.05$). This revealed that the use of cooperative learning strategy significantly improved the performance of the students in chemistry in the experimental group compared with those in the control group who were taught using lecture method. Therefore null hypothesis which states that there is no significant difference between the academic performance of SS II chemistry students taught using cooperative learning strategy and those taught using lecture method is therefore rejected.

Null Hypothesis Three: There is no significant difference between male and female SS II chemistry students in their science process skills acquisition when exposed to cooperative learning strategy.

This hypothesis was tested with science process skills acquisition scores of male and female students who were exposed to the use of the cooperative learning strategy. The significance of the variability obtained in the scores of male and female students in experimental group were compared with the two sample t-test because of the two independent groups (males and females) involved in the test. The result of the t-test analysis is presented in Table 4.7.

Table 4.7: Result of t-test Analysis of Posttest Mean Scores of Male and Female Students in Experimental Group on TOSPS

Test	Gender	N	Mean	Std. Dev.	Std. Err.	t-obs	Df	P-value	Remarks
Posttest	Male	48	12.79	2.123	.306	1.005	85	.318	NS*
	Female	39	13.23	1.898	.304				

The result in the Table 4.7 did not revealed significant difference between the male and female students who were taught with cooperative learning strategy in their science process skills acquisition scores ($P > 0.05$). This is indicated with an observed t-value of 1.005 obtained at 85 degree of freedom. The significant level obtained in the post test was 0.318 ($P > 0.05$). These observations did not provide sufficient evidence for rejecting the null hypothesis. Therefore, the null hypothesis which states that there is no significant difference between male and female SS II chemistry students in their science process skills acquisition when exposed to cooperative learning strategy is retained.

Null Hypothesis Four: There is no significant difference between the academic performance mean scores of male and female SS II chemistry students when exposed to cooperative learning strategy.

The chemistry performance mean scores of male and female students who were taught using cooperative learning strategy were compared. The result of the two sample t-test analysis is presented in Table 4.8.

Table 4.8: Result of t-test Analysis of Posttest Mean Scores of Male and Female Students in Experimental Group on CPT

Test	Gender	N	Mean	Std. Dev.	Std. Err.	t-obs	Df	P-obs	Remarks
Posttest	Male	48	18.25	5.004	.722	0.675	85	.502	NS*
	Female	39	19.00	5.341	.855				

The result of the test in Table 4.8 did not revealed significant difference between the male and female students' academic performance in chemistry when exposed to the cooperative learning strategy (CLS). This conclusion is drawn from an observed t-value of 0.675 obtained at 85 degree of freedom. The observed significant level for the test was 0.502 ($P > 0.05$). These observations did not provide evidence for rejecting the null hypothesis. Therefore, the null hypothesis which states that there is no significant difference between the academic performance of male and female SS II chemistry students when exposed to cooperative learning strategy is retained.

4.4 Summary of Findings

The major findings from the data analysis and test of hypotheses for the study are summarized below:

1. Chemistry students taught with Cooperative Learning Strategy (CLS) have improved significantly in science process skills acquisition in the way they responded to the skills tested in the Test of Science Process Skills (TOSPS).
2. The use of cooperative learning strategy had significant effect on the academic performance of chemistry students exposed to it more than those taught uing lecture method. Evidence from student's responses has indicated that, the

difference in academic performance between chemistry students in the experimental group and those in control group was statistically significant.

3. The performance of male and female students in the science process skills acquisition when taught chemistry using cooperative learning strategy did not differ significantly.

4. The academic performance of male and female chemistry students did not differ significantly when exposed to cooperative learning strategy.

4.5 Discussion

This study investigated the impact of cooperative learning strategy on the acquisition of science process skills and academic performance among chemistry students in secondary schools in Zaria Education Zone. Four hypotheses were tested for the study.

It was indicated that the use of cooperative learning strategy significantly influenced the acquisition of science process skills of students who were exposed to it. The acquisition of science process skills of students taught chemistry with cooperative learning strategy was significantly higher than those taught with lecture method. In cooperative learning strategy, students share common goal and have different perspectives on the best way of attaining the goals. The sharing of different points of view in the attempt to achieve a common goal results in creative advance critical thinking and problem solving ability (Maheady, Harper & Mallette, 2001; Atkamis & Ergin,2008; Kanli & Yagbasan, 2007). The higher acquisition of science process skills of students taught chemistry with cooperative learning strategy is due to the opportunity students had when working in group to interact with each other, share ideas and correct one another in order to achieve common task. The finding of this study is in agreement with Igboegwu and Egbuta, (2011) who conducted a study on the effect of cooperative learning strategy and demonstration method on acquisition of science process skills by chemistry students of different levels of scientific literacy. The result of their study revealed that the use of cooperative learning strategy influenced students' acquisition of science process; students of different levels of scientific literacy acquired science process skills higher than those exposed to demonstration method. According toIgboegwu and Egbuta (2011), cooperative learning strategy significantly enhanced science process skills acquisition among chemistry students of different levels of scientific literacy better than those in demonstration method.

Teaching students using cooperative learning strategy enables student to acquire not only scientific knowledge but also science process skills. The present study also found that cooperative learning strategy enhanced the acquisition of science process skills among chemistry students. In their study (Ibe & Nwosu,2003; Damole & Adeoye, 2004; Akubuilo,2004; Arokoyu & Nna,2012) concluded that several activity teaching methods such as cooperative learning strategy enhanced students acquisition of science process skills. Contrary results were obtained by Abdullahi (2014) that the use of cooperative learning strategy does not determine students' self- efficacy, reflective thinking and acquisition of science process skills.

The academic performances of students exposed to cooperative learning strategy and those exposed to lecture method were compared. The outcome of the comparison indicated that the use of cooperative learning strategy significantly improved the academic performance of students taught chemistry with it. Their performance was indicated to be significantly higher than those taught chemistry with lecture method. Cooperative Learning Strategy (CLS) has multifaceted benefits over lecture method. Working together in cooperative groups speeds up the learning process of students and improves their academic performance (Olorukooba,2001; Killic,2008). It was emphasized (Yusuf, 2005; Shimazoe & Aldrich,2010) that cooperative learning strategy enhances students' academic performance. When learners are confronted with problems which they must solve, they are forced to reason and think critically in order to solve the problems. This is why for this study, students exposed to cooperative learning strategy performed better than those taught with lecture method. The result of this study agrees with the finding of Olorukooba (2001) who concluded that, students taught chemistry by the use of cooperative learning strategy performed significantly higher than those taught with lecture method.

Wachanga and Mwangi (2004), Ajaja and Eravwoke (2010), Olatoye, Aderogba and Aanu (2011) separately reported that the use of cooperative learning strategy is more effective than lecture method of teaching in terms of improving academic performances of students. Also Abdullahi, (2014) conducted a study on the effects of cooperative learning strategy on self-efficacy and achievement in chemistry among concrete and formal reasoners. The finding of his study revealed that, students in the cooperative classroom performed significantly better than those students in lecture classroom.Koppes (2002), Killic (2008), Gambari, James & Olumorin (2013) have separately reported the dominance of cooperative learning strategy over lecture method in terms of students academic performance. According to Gupta & Pasriji (2012); Norah (2015), students exposed to cooperative learning strategy had significantly better academic performance over those students exposed to lecture method of teaching. Cooperative Learning Strategy (CLS) is a process of working together in a group to accomplish shared goals. Teachers use cooperative learning strategy to enhance students' ability of working together. By working together, they minimize their own collective and individual ways of learning towards achieving a common goal (Okoli, 2006; Bilgin & Geban, 2006; Igboegwu & Egbuta,2011). The spirit of learning together is improved where students work cooperatively to achieve meaningful learning. Douglas (1997) argued that the use of activity oriented methods such as explicit problem – solving and conceptual instruction, cooperative learning strategy and demonstration methods, is not a determinant for students' academic performance.

The test of science process skills (TOSPS) scores of male students and female students exposed to cooperative learning strategy and were also compared. The result in revealed that the use of cooperative learning strategy significantly influenced the acquisition of science process skills of students who were exposed to it. The acquisition of science process skills of male and female students taught chemistry with cooperative learning strategy was significantly improved when exposed to it. There has not been consistent result with respect to gender in terms of acquisition of science process skills (Ajaja & Eravwoke, 2010; Ukoh, 2013). This is why the result obtained here signifies that male and female students had equal opportunity to work cooperatively and solve problems. This result is in agreement with the findings of Fredrick (2005), Olatoye, Aderogba and Aanu (2011) who found no significant interaction between instructional method and gender on performance. In their study on the effects of Biology Practical Activities on Students' Process Skills Acquisition, Nwagbo & Uzoamaka (2011) reported no interaction between method of teaching and gender on Students' process skill acquisition. Ukoh (2013), conducted a study to determine the effect of interactive invention instructional strategy and gender on NCE pre-service teachers' acquisition of science process skills. He concluded that gender was not found to be significant variable for influencing the level of acquisition of science process skills. This is contrary to the findings of Okwo and Otubah, (2007) who opined that gender is a significant factor that influences students' academic performance.

Also, the significant difference in the academic performance of males and females chemistry students exposed to cooperative learning strategy was determined. The result of the test indicated, that the academic performance of male students was not significantly different from the academic performance of female students. Results of the effects of cooperative learning strategy on academic performance of students in terms of gender havenot been consistent (Fredrick, 2005; Nwagbo & Chukelu 2011; Muhammad.2014). The result recorded that cooperative learning strategy had the same effect on academic performance of male and female students exposed to it irrespective of their sex. It means that cooperative learning strategy is gender friendly. The finding of this study is in support of the studies of Olorukooba (2001), Wachanga & Mwangi (2004) who separately concluded that, the academic performance of male and female chemistry students exposed to cooperative learning strategy was not significantly different. Also Ajaja & Eravwoke,(2010); Abdullahi,(2014) conducted their study on the effect of cooperative learning strategy on academic performance of students. They reported no significant difference in the academic performance of male and female students exposed to cooperative learning strategy. The strategy provided equal opportunity to both male and female students to share ideas, benefit one and other in order to attain common goals. The result of this study is contrary to the findings of Emmanuel (2013), who reported that the use of activity methods such as concept mapping, cooperative learning strategy is sensitive to gender in terms of academic performance; that a better performance in favour of female students was recorded.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

In this chapter this chapter, the summary of the research on the impact of cooperative learning strategy on process skills acquisition and performance in chemistry among secondary school students in Zaria Kaduna State Nigeria is presented. The chapter is presented under the following sub - headings.

5.2 Summary of the Study

5.3 Summary of Major Findings

5.4 Conclusion

5.5 Contributions to Knowledge

5.6 Recommendations

5.7 Limitations of the Study

5.8 Suggestion for Further Studies

5.2 Summary of the Study

This study determined the impact of cooperative learning strategy science process skills acquisition and performance of chemistry students exposed to CLS over those students taught using talk-chalk method.The study report was structured into five chapters. Chapter one gave the background of the study, statement of the problems, research questions and hypotheses. Chapter two contained review of related literature used for the study. The methodology used to conduct the study was stated in chapter three. In chapter four, the statistical analysis and interpretation of the findings was carried out and presented. While summary, conclusions and recommendations were presented in chapter five.

The population of the study comprised of one thousand seven hundred and fourty-three (1743) SSII science students in the public secondary schools in Zaria Education Zone. Since gender is one of the variables in this study, eleven co- educational schools with a total of 670 students comprising of 380 males and 290 female students were used. However, two schools that did not differ significantly were chosen and assigned as experimental and control groupsby means of throwing a coin accordingly. In order not to temper with the school academic calendar, intact class was used in each of the experimental and control groups. The total number of subjects used as sample size was 162; where the experimental group had a total of 87 students comprising of 48 males and 39 females while the control group consisted of 75 students with 45 males and 30 females. Four research hypotheses were formulated to answer the research questions in this study and tow instruments; Test of Science Process Skills (TOSPS) and Chemistry Performance Test (CPT) were the instruments used to collect the data for the study.

5.3 Summary of Major Findings

The major findings of the study are summarized below:

1. Chemistry students taught using cooperative learning strategy performed significantly better in their acquisition of science process skills than those taught using lecture method.
2. Chemistry students taught using cooperative learning strategy performed significantly better in academic performance than those taught using lecture method.

3. Male chemistry students taught using cooperative learning strategy did not performed better in their acquisition of science process skills than female chemistry students taught using cooperative learning strategy.
4. Male chemistry students taught using cooperative learning strategy did not performed better in academic performance than female chemistry students taught using cooperative learning strategy.

5.4 Conclusion

Based on the findings of this study, the following conclusions were made:

Cooperative Learning Strategy (CLS) has positive impact on students' process skills acquisition and academic performance among secondary school chemistry students. The strategy is also not gender sensitive.

5.5 Contributions to Knowledge

The results of the findings of this study have made the following contributions to knowledge.

1. Cooperative Instructional Package (CIP) has been designed to help students acquire science process skills by the researcher.
2. This study has established that Cooperative Learning Strategy is effective in enhancing the academic performance of students in chemistry. The Chemistry Performance Test (CPT) has been developed to test the performance of students in chemical equilibrium
3. Cooperative Learning Strategy (CLS) has been indicated to be gender friendly and so can be used in eliminating gender differences among science students.

5.6 Recommendations

Based on the findings of this study, the following recommendations are made:

1. Cooperative Instructional Packages should be designed by professional teachers to help science students learning in a cooperative setting acquire science process skills.
2. For effective instruction, chemistry teachers in secondary schools should employ the use of cooperative learning strategy because of its impact on students' academic performance.
3. Because cooperative learning strategy is gender friendly, chemistry teachers should use it to eradicate gender differences among science students.

5.7 Limitations of the Study

This study was limited to the following

1. The students were not too familiar with the processes used in cooperative learning strategy. This made it necessary to the researcher to add little time on the time allotted for introduction to explain to the students on how to go about learning in a cooperative group.
2. Insufficient time: students could not get enough time to adequately supply correct data expected from the study. This may be due to the school administrative activities
3. Language barrier: students could not supply correct data for the study as a result of language difficulty

5.8 Suggestions for Further Studies

This study determined the effect of cooperative learning strategy on science process skills acquisition and academic performance among senior secondary school students in Zaria. The following suggestions are made for further studies.

1. The relationship between science process skills and academic performance of students who are exposed to cooperative learning strategy in secondary schools could be determined since it was not covered in this study.
2. This study could be expanded to other secondary schools as well as primary and higher institutions in the remaining Education Zones of the state.

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Appendices

APPENDIX Ia

CHEMISTRY PERFORMANCE TEST (CPT)

INSTRUCTION: Attempt all the Questions from Section A and B
Section A: Answer all the questions by choosing the correct option from the letters A–D Time Allowed: $1\frac{1}{2}$ Hours

1. A reversible reaction always shows that equilibrium can only occur.(Anl)

a. at high temperature
b. at low pressure
c. in a closed vessel
d. in the presence of a catalyst

2. Dynamic equilibrium describes a situation where. (Kno)

a. a reaction gives back the reactants
b. reactant are converted to products
c. the conc. of reactants and products is equal
d. both forward and reverse reactions proceed at the same rate.

3. $NH_4Cl_{(s)} \rightarrow NH_{3(g)} + HCl_{(g)}$

From the reaction represented by the above equation, it can be predicted that the reaction can only attain equilibrium if. (Kno)

a. it is in an open system
b. it is in a closed system
c. a gaseous reactant is added
d. one of the products is removed.

4. A reaction at equilibrium can be related to free energy change if. (Apl)

a. ΔG is equal to ΔH
b. ΔG is greater than ΔH
c. ΔG is equal to $T\Delta S$
d. ΔH is equal to $T\Delta S$

5. The equilibrium of an endothermic reaction which proceeds with an increase in volume can be shifted to operate in the reverse direction by. (Apl)

a. increasing the temperature and decreasing the pressure
b. increasing the pressure and the temperature
c. decreasing the temperature and increasing the pressure
d. decreasing the pressure and the temperature.

6. In the equilibrium reaction, A $\rightleftharpoons$ C+D, more of C and D are produced when temperature is increased. Which of the following statement is a correct deduction?(Syn)

a. the reaction is exothermic in the forward direction.
b. the reaction is endothermic in the forward direction
c. the reaction does not require catalyst
d. the reaction has low activation energy

7. Carefully select which of the following conditions favour the reverse reaction in a system represented by the equation below? (Kno)

$X_{2(g)} + 2Y_{2(g)} \rightleftharpoons 2XY_{2(g)} \Delta H = -XKJmol^{-1}$

a. low temperature
b. high pressure
c. removal of XY_2
d. removal of X_2

8. Identify which of the following changes will have no effect on the equilibrium position of the reaction below? (Apl)

$CO_{2(g)} + H_2O_{(g)} \rightleftharpoons CO_{2(g)} + H_{2(g)} \Delta H=-41KJ$

a. increase in temperature
b. increase in the concentration of CO
c. removal of CO_2 from the mixture
d. decrease in pressure

9. Predict which of the following is false about an equilibrium reaction represented as shown below?(Com)

$P+Q \rightleftharpoons T + D \quad \Delta H = - X\ KJmol^{-1}$

a. increase in temperature favours the reverse reaction
b. addition of a catalyst favours only the forward reaction
c. the reactants and the products are present in the equilibrium mixture
d. the forward and reverse reactions proceed at the same rate

10. Consider the equilibrium system represented by the following equation:

$Cu^{2+}_{(aq)} + 4NH_{3(aq)} \rightleftharpoons [Cu(NH_3)]^{2+}_{(aq)}$

(light blue) (deep blue)

It infers that, the deep blue colour will fade on adding. (Anl)

a. $Cu_2{}^{+}_{(aq)}$

b. $H_2SO_{4(aq)}$

c. $NH_{3(aq)}$

d. $NaCl_{(aq)}$

11. Identify which of the following statements about catalysts in reversible reactions is correct. (Anl)

a. they have no effect on the activation energy

b. they alter equilibrium position

c. they lower the value of the heat energy

d. they affect the forward and reverse reaction rates equally.

12. Consider the following equilibrium reaction.

$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)} \Delta H = -$ ve

Justify which of the following conditions will affect the equilibrium position as well as the value of the equilibrium constant?(Eva)

a. decrease in concentration

b. increase in pressure

c. increase in temperature

d. addition of a catalyst

13. $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \Delta H = -90KJ$.

In the equation above,it can be concluded that the yield of ammonia can be decreased by. (Eva)

a. increasing the temperature

b. increasing the pressure

c. adding a catalyst

d. removing ammonia as it is formed.

14. The example of a gas which does not produce ions in water is (Com)

a. NH_3

b. HCl

c. CH_4

d. CO_2

15. The solubility product of $Cu(IO_3)_2$ is 1.08 x 10^{-7}. Assuming that neither ions react appreciably with water to form H^+ and OH^-, what is the solubility of thissalt?(Apl)

a. 2.7 x 10^{-8}moldm^{-3}

b. 2.8 x 10^{-8}moldm^{-3}

c. 9.0 X 10^{-8} $moldm^{-3}$

d. 3. 0 x $10^{-3}$$moldm^{-3}$

16. From the expression below

$K_c = \frac{[C]^p [D]^q}{[A]^m [B]^n}$

It can be concluded that, the letter K_c stands for(Eva)

a. equilibrium position

b. equilibrium constant

c. equilibrium rate

d. standard equilibrium

17. For the reaction $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$. The equilibrium constant was found to be 3.6 x 10^{-15} at 773K. Calculate the free energy change for the reaction at this temperature. (R= $8.314KJMol^{-1}$). (Apl)

a. $-99.9kJmol^{-1}$

b. $+230.2kjmol^{-1}$

c. $-230.2kJmol^{-1}$

d. $+99.9kJmol^{-1}$

18. What inference could you draw when sodium ethanoate undergoes hydrolysis the resulting solution. (Com)

a. will be acidic

b. has a PH of 6.0

c. will be neutral

d. will be alkaline

19. Identify the conjugate base of NH_4^+. (Kno)

a. NH^{2-}
b. H^+
c. N_2H_4
d. NH_3

20. The forward reaction of this equation 2HI(g) $\rightleftharpoons H_{2(g)} + I_{2(g)}$ is endothermic. If the temperature of the reaction vessel is decreased, it can be summarized that (Syn)

A. more I_2 will be formed

B. more H_2 is formed

C. more HI is decomposes

D. more HI is formed

Section B: Fill in the blank spaces from (21 – 30) and True or False from (31 – 40) appropriately

21. When the forward reaction in a reversible reaction is exothermic, then the backward reaction is said to be ………………………………………..............................(Kno)
22. ……………………………………… states that the rate of a reaction is directly proportional to the active masses of the reactants and products. (Kno)
23. The equilibrium constant is not affected by changes in concentration, pressure or catalyst, but varies with changes in …………………………………………….. (Com)
24. The position of equilibrium is affected by changes in ………………………. ……………………….. and ………………………….............................(Syn)
25. The simple relationship between the equilibrium constant (K_c) and change in standard free energy (ΔG^0) can be related as …………………………………………….. (Anl)
26. …………………………………. can be explained as a reaction that can be made to proceed via both forward and backward direction. (Com)
27. The equilibrium constant for this reaction $3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$ can be written as …………………………………………………….................. (Syn)
28. ………………………………………… can be explained as a reaction in which heat is absorbed from the surrounding. (Syn)
29. …………………………………. has no effects on system in equilibrium but only shortens the rate at which equilibrium will be reached. (Anl)
30. When a system in equilibrium is affected by an external factor, the equilibrium shifts to a direction in order to oppose the effect of the change and restore back equilibrium. This statement is called ………………………………………………………… (Kno)
31. Sublimation of ammonium chloride is an irreversible reaction. (Com)
32. If the equilibrium constant of a reaction is large, then the equilibrium shifts to the right. (Anl)
33. In Haber process, increase in pressure will favour forward reaction. (Eva)
34. An increase in temperature on system in equilibrium favours exothermic reaction while a decrease in temperature favours endothermic reaction. (Anl)
35. Considering this reaction in equilibrium $A \rightleftharpoons C + D$, the forward reaction can be made to proceed by decreasing the concentration of A. (Eva)
36. The equilibrium position of a reaction can only be kept constants by making the conditions of the reaction to remain constant. (Syn)

37. The concentration of a reaction raised to the power of its stoichiometric value as in the balanced equation is called active mass. (Com)
38. In aqueous solution, a strong acid will dissociate to give a weak conjugate base, while a weak acid will dissociate to give a strong conjugate base. (Apl)
39. In cation hydrolysis, the resulting solution will be alkaline while in anion hydrolysis, the resulting solution will be acidic.(Syn)
40. A reaction is said to be at equilibrium if ΔH is equal to $T\Delta S$. (Eva)

Note: Kno, Com, Apl, Anl, Syn and Evaindicate the levels of the cognitive domain each item is set to assess.

Appendix Ib

CHEMISTRY PERFORMANCE TEST (CPT)

Marking Scheme

Section A

1C

2D

3B

4E

5C

6B

7D

8D

9B

10B

11D

12C

13A

14C

15C

16B

17C

18D

19D

20D

Total = 1mark × 20 = 20marks

Section B

21. At equilibrium

22. Law of mass action

23. Temperature

24. Concentration, pressure and temperature

25. $\Delta G^0 = - RTlin K = - 2.303RTlog_{10}^{k}$

26. Reversible reaction

27. Kc = $\frac{[NH3]^2}{[H2]^3[N2]^1}$

28. Endothermic reaction

29. Catalyst

30. Le – chatelier's principle

31. FALSE

32. TRUE

33. TRUE

34. FALSE

35. FALSE

36. TRUE

37. TRUE

38. TRUE

39. FALSE

40. TRUE

From Section A and B Each Question = 1 mark × 40 = 40 marks

Appendix Ic

CHEMISTRY PERFORMANCE TEST (CPT)ANSWER SHEET

TIME ALLOWED: $1\frac{1}{2}$ HOUR

SEX: MALE…… FEMALE……

INSTRUCTIONS: Use HB pencil to shade the correct answer from A - D, fill in the blank spaces or indicate T for true and F for false

1.	=A=	=B=	=C=	=D=	21. …………………………………
2.	=A=	=B=	=C=	=D=	22. ………………………………....
3.	=A=	=B=	=C=	=D=	23. …………………………………
4.	=A=	=B=	=C=	=D=	24. ………………………………....
5.	=A=	=B=	=C=	=D=	25. …………………………………
6.	=A=	=B=	=C=	=D=	26. …………………………………
7.	=A=	=B=	=C=	=D=	27. …………………………………
8.	=A=	=B=	=C=	=D=	28. ………………………………....
9.	=A=	=B=	=C=	=D=	29. …………………………………
10.	=A=	=B=	=C=	=D=	30. …………………………………
11.	=A=	=B=	=C=	=D=	31. =T= or =F=
12.	=A=	=B=	=C=	=D=	32. =T= or =F=
13.	=A=	=B=	=C=	=D=	33. =T= or =F=
14.	=A=	=B=	=C=	=D=	34. =T= or =F=
15.	=A=	=B=	=C=	=D=	35. =T= or =F=
16.	=A=	=B=	=C=	=D=	36. =T= or =F=
17.	=A=	=B=	=C=	=D=	37. =T= or =F=
18.	=A=	=B=	=C=	=D=	38. =T= or =F=
19.	=A=	=B=	=C=	=D=	39. =T= or =F=
20.	=A=	=B=	=C=	=D=	40. =T= or =F=

APPENDIX IIa

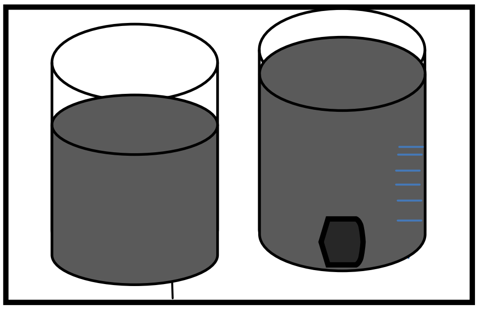
TEST OF SCIENCE PROCESS(TOSPS)

An instrument designed to measure process skills Acquisition among science students

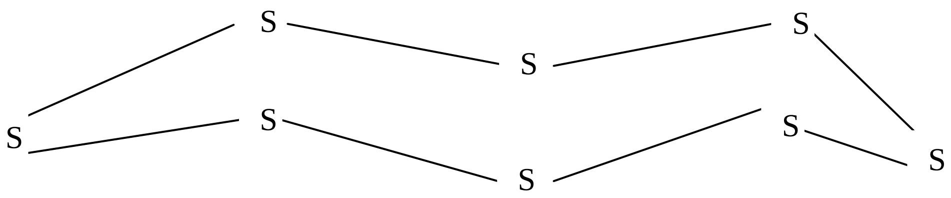
INSTRUCTIONS **TIME ALLOWED: 1 HOUR**

1. Attempt all question. SEX: Male …… Female …….
2. Do not write on the question paper. Write all your answers on the answer sheet provided.
3. Each question is followed by four (4) alternative responses. Letter A-D. Choose the correct response for each question and shade the letter of response you choose from the answer sheet.

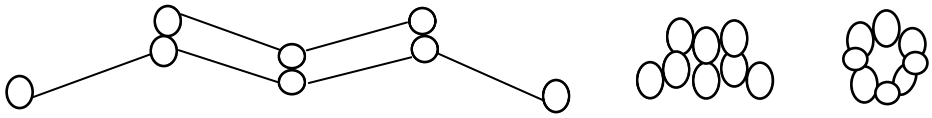
2. A jar containing water coloured with potassium permanganate is diluted many times with water to find out if matter consists of many tiny particles. Which of the following observation is correct?
   a. The colour doses not change no matter how many times it was diluted.
   b. The colour fades a bit each time but never completely disappears.
   c. The colour gets stronger each time it is diluted.
   d. The colour disappears completely the first time it is diluted.
3. Measure $250cm^3$ of water using a measuring cylinder. Carefully drop a small piece of stone (provided) in to the measuring cylinder. What do you observe?
   a. The volume of the water is reduced
   b. The piece of stone get dissolved
   c. The level of the water rises
   d. The volume of the water increase.



4. The structural formular of sulphur (S_8) is given below:



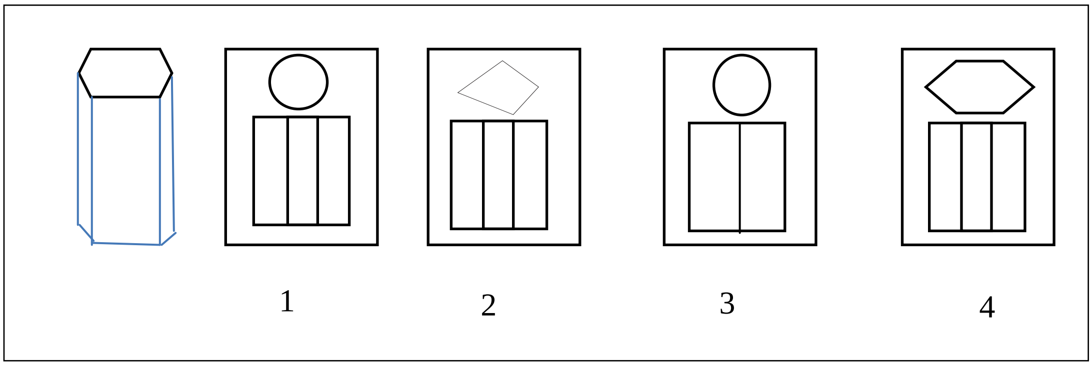
Which of the models below correctly represent the structure of sulphurs?



I II III

a) I only b) I, II & III c) II & III only d) III only

4.

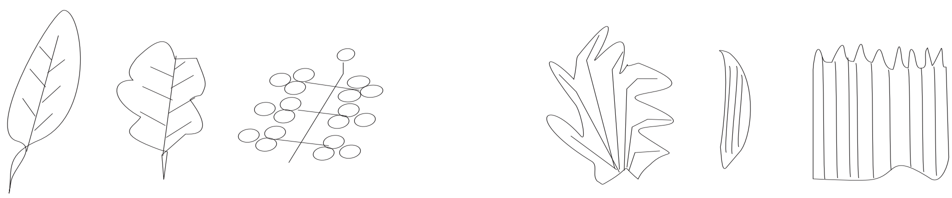


This is a picture of a box and four drawings (1,2,3,4) which drawing shows the best representation of the box?

(A) Diagram 1 (B) Diagram 2

(B) Diagram 3 (D) Diagram 4

5. Terry had divided the leaves in his leaf collection into two groups

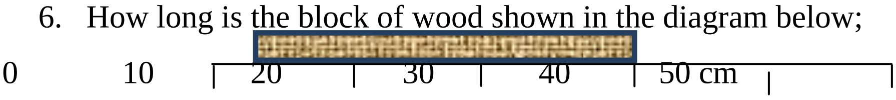


A B

Identify the leave that will fit into group B.

Fig. 3.2 A B C D

6. How long is the block of wood shown in the diagram below;



a) 10cm
b) 20cm
c) 25cm
d) 35cm

7. You are provided with two measuring cylinders of different capacity. One of the cylinders is graduated while the other is not. Fill the graduated cylinder with water to the mark on it and pour the water in the graduated cylinder. What is the capacity of the graduated cylinder when filled to the mark in ml?
   a. 150ml
   b. 1.5ml
   c. 1500ml
   d. 2000ml

8. Assuming that you are in a room with only one window, floor tiles and a chair inside it and you are asked to measure the size of the room. Which of the following means is not suitable for you to accomplish the task?
   a. Your foot length
   b. Floor tiles
   c. Chair length
   d. Window length

9. To measure the weight of a small quantity of solute sample using a weighing balance, All of the following is necessary except;
   a. Measure the weight of the container in to which sample is to be placed
   b. Determine the weight of the weighing balance
   c. Measure the weight of the container plus sample

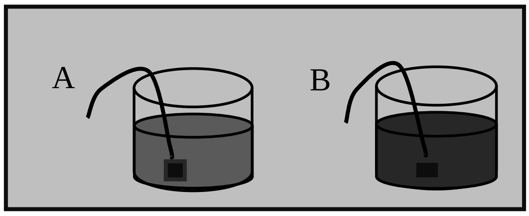
d. Subtract the weight of the container from the weight of the container plus sample.

10. Below is a diagram of a piece of metal rod with an irregular shape.

To measure the actual length of the rod it is always advisable to use;

a) A wooden ruler
b) A metal ruler
c) Measuring tape
d) A bent wooden ruler

11. A teabag was placed in each glasses A & B of water for two minutes, why is that the tea in glass B darker than the tea in glass A?



a. There is more water in glass A
b. Glass one is larger than glass B
c. The water temperature in glass Bis higher than the water temperature in glass B.
d. There is less water in glass B

12. An iron container is weighted after air in it has been pumped out (evacuated), then it is filled with hydrogen and weighed again. What inference can be deduced about the weight of the container full of hydrogen compared to the weight of the evacuated container?

a. Less
b. Greater
c. Greater or less depending on the value of the gas in the container.
d. Greater or less depending on the temperature of the gas in the container

13. A student conducting qualitative analysis on three (3) samples A,B and C discovered that sample A on addition of some volumes of water requires 2 minutes to dissolved, while to sample B some drops of conc. acid has to be added before it dissolve and sample C requires conc. acid, heat and equal volume of water before it dissolve. What inference can you draw from the experiment?

a. The volume of water used is too small to dissolve the sample
b. The quantity of samples used must be reduced for the samples to dissolve.
c. Sample "A" is more reactive than sample B and C.

d. Sample “B” and “C” are more resistant to heat than sample “A”.

14. A bean seed was planted in a dry soil, and placed in a dark cupboard. After 5 days the seed did not germinate. Another seed was planted in a dry soil, watered and placed in the same dark cupboard. After 5 days, it germinated. What conclusion/ inference can you draw for this experiment?

   a. That light is needed for germination
   b. That dry soil is needed for germination
   c. That water is needed for germination
   d. The humidity is needed for germination.

15. You are provided with two solutions A and B. On putting litmus paper in A there was no change in colour observed. But in solution B the colour of the litmus paper changes to red. Which of the following is the correct inference that could be drawn from the experiment?

   a. That both solution A and B are unreactive to litmus
   b. That solution B is acidic
   c. The solution A is basic
   d. That solution B is basic.

16. Which of science best describe the drawing below?

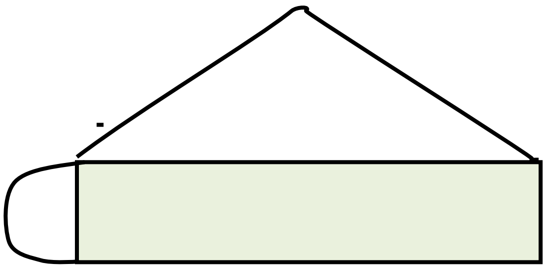
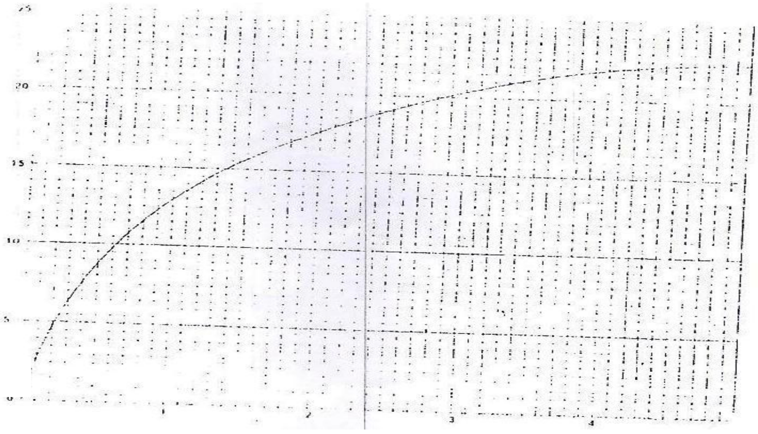


Fig. 3.3

a. A house with round window
b. A rectangle with triangle on top and a half circle on the left
c. A triangle with a rectangle underneath and a half circle in the right
d. A half circle with rectangle on the right and a triangle in the left.

17. 50g of calcium carbonate were reacted with excess of dilute hydrochloric acid. The mass of gas given off is shown on the graph.



The mass of carbon (IV) oxide gas produce after 2 minutes is

a). 5g

b). 20g

c).17g

d). 17.5g

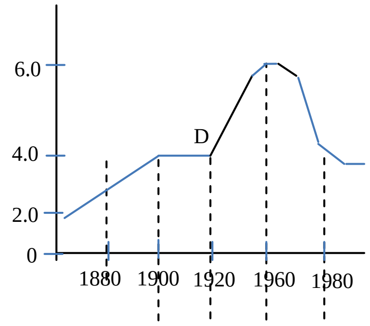
18. While investigating the effects of temperature on reaction rate, a student obtained the following result.

Experiment	Mass of zinc (g)	Temperature (°C)	Time taken to dissolve in HCl(s)	State of Zinc
A	2.0	5	400	Zinc foil
B	2.0	15	200	-dust-
C	2.0	25	100	-dust-
D	2.0	35	50	-dust-
E	2.0	45	25	-dust-
F	2.0	15	5	Zinc powder

In which of the experiment is the reaction rate faster?

a. B
b. D
c. F.
d. A

19. Sulphr (1V) oxide is one of the gases emitted into the atmosphere by industries. Below is a graph which shows the annual emission of sulphur (IV) oxide into the atmosphere.



Interprete from the graph what happens to the amount of sulphur (iv) oxide emitted between the years 1920-1940?

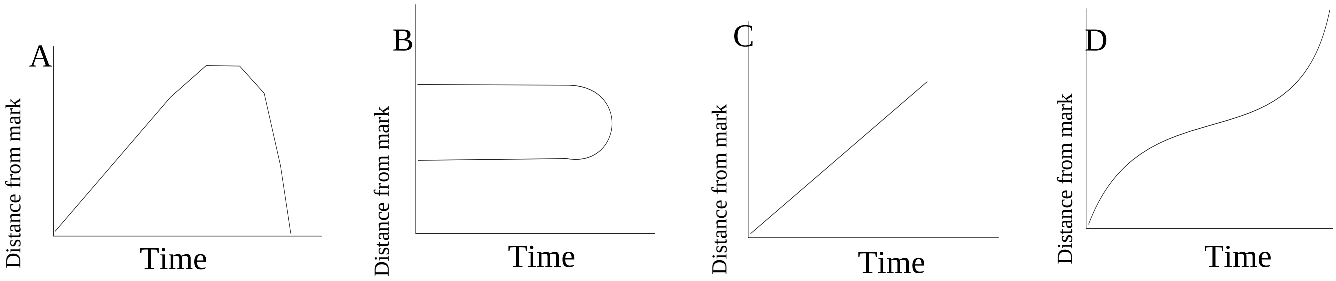
a. The amount increases rapidly

b. The amount remain the same

c. The amount decreases rapidly

d. The amount becomes about higher in 1940.

20. Jane walks away from a mark on the floor at a steady rate and then walks back towards it. Which distance graph below would describe his walk?



21. Read the following story and answer the question that follows:

She could not get teaspoons of sugar to dissolve in her iced tea unless she stirred for a long time. She knew she could easily dissolve the sugar in hot tea she wandered I the temperature made a difference in the amount of time it took for the sugar to dissolve. After trying five different temperatures, the hypothesis she was probably testing was?

a. The colder the tea, the quicker the sugar will dissolve

b. The sugar will dissolve at the same rate in 600 tea as it does in 1000 tea

c. The hotter the tea the quicker the sugar will dissolve

d. The temperature of the tea does not affect how rapidly the sugar dissolve

22. John cuts grass for seven different neighbours, each week he makes the rounds with his lawnmower, the grass is usually different in the lawns. In some lawns it is tall but not in others. He begins to make hypothesis about the height of grass. Which following as a suitable hypothesis he could test?

a. Lawn moving is more difficult when the weather is high

b. The amount of fertilizers a lawn receives is important.

c. lawns that receive more water have longer grass .

d. The more hills there are in a lawn the harder it is cut.

23. Sani wanted to know if temperature can affect the rate of a chemical reaction. He sets 2-experiments under varying temperatures using the same reactants. He decided to keep the concentration and pressure of the reactant constant. At the end of the reaction, he

recorded the time each reaction gets to completion. Which of the following can be hypothesis/ intelligent guess be?

a. The rate of the reaction is affect by the nature of the reactant used.

b. The rate of the reaction is affected by the temperature

c. The concentration of the reactant determined the rate of the reaction

d. The rate of the reaction is affected by pressure.

24. He wanted to know how long is the distance from Zaria to Kano, in terms of transport charges. He only knew that Kaduna is 50km from Zaria and the amount charged is ₦100. When he gets to the garage he was told that the transport charges to Kano is ₦75.00 which of the following can be an appropriate hypothesis for the statement.

a. The distance from Zaria to Kaduna is shorter

b. The distance from Zaria to Kano is shorter

c. The distance from Zaria to Kano is determined by the speed of the vehicle used.

d. The distance from Zaria to Kaduna is determined by the brand of vehicle used.

25. A science class wanted to test a variables or factor that might affect plant height. The following is a list of variables they felt could be tested: (i) Amount of light; (ii) amount of moisture; (iii). Soil types and; (iv). Change in temperature, which of the following could be a possible hypothesis for the class experiment?

a.An increase in temperature will cause an increase in plant height.

b. A plant left in the light will be greener than a plant left in the dark

c. An increase in sunlight causes an increase in the amount of moisture lost by the plant.

d. A plant is sandy soil loses more water than plant in clay soil.

Appendix IIb

TEST OF SCIENCE PROCESS SKILLS (TOSPS)

Marking Scheme

1B

2C

3B

4D

5C

6C

7A

8D

9B

10C

11C

12B

13C

14C

15B

16B

17C

18C

19B

20A

21C

22C

23B

24B

25A

Total = Each Question = 1mark × 25 = 25marks

Appendix IIc

TEST OF SCIENCE PROCESS SKILLS (TOSPS)ANSWER SHEET

TIME ALLOWED: 1 HOUR

SEX: MALE…… FEMALE……

INSTRUCTIONS: Use HB pencil to shade the correct answer from A - D

1.	=A=	=B=	=C=	=D=	21.	=A=	=B=	=C=	=D=
2.	=A=	=B=	=C=	=D=	22.	=A=	=B=	=C=	=D=
3.	=A=	=B=	=C=	=D=	23.	=A=	=B=	=C=	=D=
4.	=A=	=B=	=C=	=D=	24.	=A=	=B=	=C=	=D=
5.	=A=	=B=	=C=	=D=	25.	=A=	=B=	=C=	=D=
6.	=A=	=B=	=C=	=D=					
7.	=A=	=B=	=C=	=D=					
8.	=A=	=B=	=C=	=D=					
9.	=A=	=B=	=C=	=D=					
10.	=A=	=B=	=C=	=D=					
11.	=A=	=B=	=C=	=D=					
12.	=A=	=B=	=C=	=D=					
13.	=A=	=B=	=C=	=D=					
14.	=A=	=B=	=C=	=D=					
15.	=A=	=B=	=C=	=D=					
16.	=A=	=B=	=C=	=D=					
17.	=A=	=B=	=C=	=D=					
18.	=A=	=B=	=C=	=D=					
19.	=A=	=B=	=C=	=D=					
20.	=A=	=B=	=C=	=D=					

APPENDIX III

LESSON PLAN FOR THE EXPERIMENTAL GROUP

Lesson One

Topic: Chemical Equilibrium

Level: SS II

Length of the class period: 90 minutes

Model of Teaching: Cooperative learning (Jigsaw) model

Behavioural Objectives:

By the end of the lesson, the students should be able to:

1. Define a reversible reaction.
2. Mention some natural processes that occur reversibly.
3. Define chemical equilibrium
4. Identify some characteristic properties of a system in equilibrium.
5. Interprete the meaning some information obtained from the system at equilibrium.

Instructional materials: Beakers with water, worksheets for all students, Role cards and social names of groups, copy of study notes to all expert groups;

1. Meaning of a reversible reaction.
2. Some natural processes that occur reversibly.
3. Meaning of chemical equilibrium
4. Characteristic properties of a system in equilibrium.
5. Information obtained from the system at equilibrium.

Previous Knowledge: The students are familiar with the terms reactants and products in a chemical reaction.

Introduction: The teacher introduces the lesson by writing the topic of the lesson on the board and explains to them what they are expected to do during activity exercise (15min).

Presentation: The teacher presents the lesson in the following steps (60 minutes).

Step I: The teacher starts the lesson by explaining to the students that they are going to learn the meaning of reversible reactions and chemical equilibrium using cooperative learning strategy where all of them will work cooperatively, and that the success of the group depends on the success of the individual member of the group.

Step II: The teacher groups the students into a cooperative learning group comprising of five to six students per group making sure that the groups are heterogeneous.The teacher also tells the group their tasks.

Group Tasks:

1. Collect and distribute the materials
2. Take turn reading and highlighting the important information
3. As a group, decide what information should be highlighted
4. As a group, answer the questions
5. Each member must fill in the activity sheet
6. Return the materials and group member activity sheet

Step III: The teacher tells what the students are expected to be doing from the beginning to the end of the lesson including the social skills they are expected to learn and apply in their interactions with one another during the group work. These skills may include using names, expert names, timing, asking questions and the rest. The teacher also discusses the activity outline for each expert group.

Activity outline for Expert Group (EGR)

A: Members of this group are to discuss the following specific areas:

1. Meaning of reversible reactions
2. Examples of reversible reactions

B: Members of this group are to discuss the following specific areas:

1. Mention some natural processes that occur reversibly
2. Discuss the natural processes that occur reversibly

C: Members of this group are to discuss the following specific areas:

1. Chemical equilibrium
2. Describe some examples of chemical equilibrium
3. State the condition for chemical equilibrium to occur

D: Members of this group are to discuss the following specific areas:

1. Characteristic properties of a system in equilibrium.
2. Meaning of information obtained from the system at equilibrium.

Roles of Expert Group Members:

Organizer: collection of group folder containing materials, distribute materials to group members, return materials to folders then to the teacher

Reader: Reads the group task to the group

Timer: Keeps the time and makes sure everyone contributes to answer the questions

Encourager: Encourages group members, decides on the order the members will read the task given to them.

Specific procedure:

To begin the lesson, the teacher gives group names written on a card. Each individual member of the group will then be given specific task to work/study. His expert name attached to the study note of the task given to his/her will be provided to him/her. Each expert will be asked to study his/her task for some time. No student in the same group will be allowed to see the task given to his fellow group member students studying the same task from each group will then be asked to form expert groups where they will study collectively the task and record useful information on the worksheet earlier provided for the purpose of feedback to his/her main group.

Members of the expert groups will after sometimes be asked to break and go back to their main groups where each expert will explain his/her task to the remaining members of the group. Other members of the group will be encouraged to ask questions and clarifications from the experts. As the group discussion is on, members of the group were assigned to perform certain role like the time keeper, questioner, reader, reminder etc, will be doing their job.

Evaluation: The teacher evaluates the lesson by asking the students questions based on bahavioural objectives (10 minutes).

Conclusion: The teacher concludes the lesson by collecting students' worksheet papers for assessment (5 minutes).

LESSON PLAN FOR THE EXPERIMENTAL GROUP

Lesson Two

Topic: Law of mass action and Equilibrium constant

Level: SS II

Length of the class period: 90 minutes

Model of Teaching: Cooperative learning (Jigsaw) model

Behavioural Objectives:

By the end of the lesson, the students should be able to:

1. State the law of mass action.
2. Derive the equation for equilibrium constant.
3. Express the equilibrium constant of some reactions.
4. State the relationship between equilibrium constant and free energy in equation.

Instructional materials: charts displaying some chemical reactions, worksheets for all students, Role cards and social names of groups, copy of study notes to all expert groups;

1. The law of mass action.
2. Derivation of the equation for equilibrium constant.
3. Expression of the equilibrium constant of some reactions.
4. Relationship between equilibrium constant and free energy in equation.

Previous Knowledge: The students have been taught the meaning of the term concentration

Introduction: The teacher introduces the lesson by writing the topic of the lesson on the board and explains to them what they are expected to do during activity exercise (15min).

Presentation: The teacher presents the lesson in the following steps (60 minutes).

Step I: The teacher starts the lesson by explaining to the students what they are going to learn i.e, the meaning of reversible reactions and chemical equilibrium using cooperative learning strategy where all of them will work cooperatively, and that the success of the group depends on the success of the individual member of the group.

Step II: The teacher then groups the students into a cooperative learning group comprising of five to six students per group and making sure that the groups are heterogeneous. The teacher gives the groups their tasks

Group Tasks:

1. Collect and distribute the materials
2. Take turn reading and highlighting the important information
3. As a group, decide what information should be highlighted

4. As a group, answer the questions
5. Each member must fill in the activity sheet
6. Return the materials and group member activity sheet

Step III: The teacher then tells the students what they are expected to be doing from the beginning to the end of the lesson including the social skills they are expected to learn and apply in their interaction with one another during the group work. These skills may include using names, expert names, timing, asking questions and the rest. The teacher proceeds to briefly explain the activity outline of the expert groups.

Activity outline for Expert Group (EGR)

A: Members of this group are to discuss the following specific areas:

1. Define active mass of a substance
2. State the law of mass action

B: Members of this group are to discuss the following specific areas:

1. Identify a named reversible reaction
2. Use the equation of the reaction you identified to derive the expression of equilibrium constant for the reaction.

C: Members of this group are to discuss the following specific areas:

1. Find out more examples of reversible reactions
2. Express the equilibrium constants of the reactions you gave examples

D: Members of this group are to discuss the following specific areas:

1. What does it mean when the Kc is less than 1
2. The relationship between equilibrium constant and free energy

Roles of the Expert Group Members:

Organizer: collection of group folder containing materials, distribute materials to group members, return materials to folders then finally to the teacher

Reader: Reads the group task to the group

Timer: Keeps the time, makes sure everyone contributes to answer the questions

Encourager: Encourages group members, decides on the order the members will read the task given to them.

Specific procedure:

To begin the lesson, the teacher gives group names written on a card. Each individual member of the group will then be given specific task to work/study. His expert name attached to the study note of the task given to his/her will be provided to him/her. Each expert will be asked to study his/her task for some time. No student in the same group will be allowed to see the task given to his fellow group member students studying the same task from each group will then be asked to form expert groups where they will study collectively the task and record useful information on the worksheet earlier provided for the purpose of feedback to his/her main group.

Members of the expert groups will after sometimes be asked to break and go back to their main groups where each expert will explain his/her task to the remaining members of the group. Other members of the group will be encouraged to ask questions and clarifications from the experts. As the group discussion is on, members of the group were assigned to perform certain role like the time keeper, questioner, reader, reminder etc, will be doing their job.

Evaluation: The teacher evaluates the lesson by asking the students questions based on bahavioural objectives (10 minutes).

Conclusion: The teacher concludes the lesson by collecting students' worksheet papers for assessment (5 minutes).

LESSON PLAN FOR THE EXPERIMENTAL GROUP

Lesson Three

Topic: Le-chatelier's principle

Level: SS II

Length of the class period: 90 minutes

Model of Teaching: Cooperative learning (Jigsaw) model

Behavioural Objectives:

By the end of the lesson, the students should be able to:

1. State Le-Chatelier's Principles.
2. List factors that can affect the system in equilibrium.
3. Explain the effect of change in concentration of reactants or products.
4. Use the expression of equilibrium constant to explain effect of change in concentration.

Instructional materials: Beakers, permanganate, worksheets for all students, Role cards and social names of groups, copy of study notes to all expert groups;

Previous Knowledge: The students are familiar with the factors that affect the rate of chemical reaction

Introduction: The teacher introduces the lesson by asking the students to mention the factors affecting the rate of reactions and writes the new topic of the lesson on the board and tells them what they are expected to do during activity exercise (15 minutes).

Presentation: The teacher presents the lesson in the following steps (60 minutes).

Step I: The teacher begins the lesson by explaining to the students what they are going to learn i.e, Le – chatelier's principle and chemical equilibrium using cooperative learning strategy where all of them will work cooperatively, and that the success of the group depends on the success of the individual member of the group.

Step II: The teacher groups the students into a cooperative learning group comprising of five to six students per group and making sure that the groups are heterogeneous. The teacher also gives expert groups their tasks.

Group Tasks:

1. Collect and distribute the materials
2. Take turn reading and highlighting the important information
3. As a group, decide what information should be highlighted
4. As a group, answer the questions
5. Each member must fill in the activity sheet

6. Return the materials and group member activity sheet

Step III: The teacher explains to the students what they are expected to be doing from the beginning to the end of the lesson including the social skills they are expected to learn and apply them in their interaction with one another during the group work. These skills may include using names, expert names, timing, asking questions and the rest. The teacher briefly gives the activity outline of the expert groups.

Activity outline for Expert Group (EGR)

A: Members of this group are to discuss the following specific areas:

1. Le-chatelier's principle
2. Factors affecting the rate of a reaction

B: Members of this group are to discuss the following specific areas:

1. Concentration of a reaction
2. Effect of change in concentration of reactants or products

C: Members of this group are to discuss the following specific areas:

1. Give a named reversible reaction
2. Use Le-chatelier's principle to explain effect of change in concentration to the system in equilibrium of reactants in the reaction you gave

D: Members of this group are to discuss the following specific areas:

1. Write and name any reversible reaction
2. Effect of change in concentration on equilibrium constant

Roles of Expert Group Members:

Organizer: collection of group folder containing materials, distribute materials to group members, return materials to folders then to the teacher

Reader: Reads the group task to the group

Timer: Keeps the time, makes sure everyone contributes to answer the questions

Encourager: Encourages group members, decides on the order the members will read the task given to them.

Specific procedure:

To begin the lesson, the teacher gives group name written on a card. Each individual member of the group will then be given specific task to work/study. His expert name attached to the study note of the task given to his/her will be provided to him/her. Each expert will be asked to study his/her task for some time. No student in the same group will be allowed to see the task given to his fellow group member students studying the same task from each group will then be asked to form expert groups where they will study collectively the task and record useful information on the worksheet earlier provided for the purpose of feedback to his/her main group.

Members of the expert groups will after sometimes be asked to break and go back to their main groups where each expert will explain his/her task to the remaining members of the group. Other members of the group will be encouraged to ask questions and clarifications from the experts. As the group discussion is on, members of the group were assigned to perform certain role like the time keeper, questioner, reader, reminder etc, will be doing their job.

Evaluation: The teacher asks the students questions based on behavioural objectives (10 minutes).

Conclusion: The teacher concludes the lesson by collecting students' worksheet papers for assessment (5 minutes).

LESSON PLAN FOR THE EXPERIMENTAL GROUP

Lesson Four

Topic: Effect of change in pressure on system in equilibrium

Level: SS II

Length of the class period: 90 minutes

Model of Teaching: Cooperative learning (Jigsaw) model

Behavioural Objectives:

By the end of the lesson, the students should be able to:

1. Define pressure
2. Identify gaseous substances from reversible reactions
3. Explain the effect of change in pressure on system in equilibrium.
4. Use an equation to explain the effect of change in pressure on the system.

Instructional materials: Syringe**,** worksheets for all students, Role cards and social names of groups, copy of study notes to all expert groups;

1. Define pressure
2. Gaseous substances from reversible reactions
3. The effect of change in pressure on system in equilibrium.
4. Effect of change in pressure on the system of a named reaction.

Previous Knowledge: The students have been taught the factors that affect the rate of chemical reaction

Introduction: The teacher introduces the lesson by reviewing the factors affecting the rate of reactions and writes the new topic of the lesson on the board and explains to the students what they are expected to do during activity exercise (15 minutes).

Presentation: The teacher presents the lesson in the following steps (60 minutes).

Step I: The teacher starts the lesson by explaining to the students that they are going to learn the meaning of pressure and its effect on chemical equilibrium using cooperative learning strategy where all of them will work cooperatively, and that the success of the group depends on the success of the individual member of the group.

Step II: The teacher groups the students into a cooperative learning group comprising of five to six students per group and makes sure that the groups are heterogeneous. The teacher identifies the tasks of the expert group.

Group Tasks:

1. Collect and distribute the materials
2. Take turn reading and highlighting the important information

3. As a group, decide what information should be highlighted
4. As a group, answer the questions
5. Each member must fill in the activity sheet
6. Return the materials and group member activity sheet

Step III: The teacher then explains to the students what they are expected to be doing from the beginning to the end of the lesson including the social skills they are expected to learn and apply them in their interaction with one another during the group work. These skills may include using names, expert names, timing, asking questions and the rest. The teacher gives the activity outline of the expert groups.

Activity outline for Expert Group (EGR)

A: Members of this group are to discuss the following specific areas:

1. Definition of pressure and its units
2. Description of pressure of a substance

B: Members of this group are to discuss the following specific areas:

1. Units of amount and volume of a substance
2. Identify gaseous substances from reversible reactions

C: Members of this group are to discuss the following specific area:

1. The effect of change in pressure on system in equilibrium.
2. Compare between the effect of concentration and pressure of a system in equilibrium

D: Members of this group are to discuss the following specific areas:

1. Classify substances into solid, liquid and gas from a named reversible reaction.
2. Effect of change in pressure on system in equilibrium of the reaction you identified.

Roles of Expert Group Members:

Organizer: collection of group folder containing materials, distribute materials to group members, return materials to folders then to the teacher

Reader: Reads the group task to the group

Timer: Keeps the time and makes sure everyone contributes to answer the questions

Encourager: Encourages group members, decides on the order the members will read the task given to them

Specific procedure:

To begin the lesson, the teacher gives group name written on a card. Each individual member of the group will then be given specific task to work/study. His expert name attached to the study note of the task given to his/her will be provided to him/her. Each expert will be asked to study his/her task for some time. No student in the same group will be allowed to see the task given to his fellow group member students studying the same task from each group will then be asked to form expert groups where they will study collectively the task and record useful information on the worksheet earlier provided for the purpose of feedback to his/her main group.

Members of the expert groups will after sometimes be asked to break and go back to their main groups where each expert will explain his/her task to the remaining members of the group. Other members of the group will be encouraged to ask questions and clarifications from the experts. As the group discussion is on, members of the group were assigned to perform certain role like the time keeper, questioner, reader, reminder etc, will be doing their job.

Evaluation: The teacher evaluates the lesson by asking the students questions based on bahavioural objectives (10 minutes).

Conclusion: The teacher concludes the lesson by collecting students’ worksheet papers for assessment (5 minutes).

LESSON PLAN FOR THE EXPERIMENTAL GROUP

Lesson Five

Topic: Effect of changes in temperature on the system in equilibrium

Level: SS II

Length of the class period: 90 minutes

Model of Teaching: Cooperative learning (Jigsaw) model

Behavioural Objectives:

By the end of the lesson, the students should be able to:

1. Identify in reversible, an endothermic or exothermic reaction.
2. Explain effect of change in temperature on system in equilibrium.
3. Describe the effect of change in temperatures on a system in equilibrium from written equation.
4. Explain the effect of catalyst on a system in equilibrium.

Instructional materials: A chart of energy profile diagram**,** worksheets for all students, Role cards and social names of groups, copy of study notes to all expert groups;

1. Endothermic and exothermic reaction.
2. Effect of change in temperature on system in equilibrium.
3. Description of the effect of change in temperatures on a system from a given equation.
4. Explain the effect of catalyst on a system in equilibrium.

Previous Knowledge: The students have learnt the meaning of temperature and the instrument used for measuring temperature

Introduction: The teacher introduces the lesson by asking students to define temperature and writes the new topic of the lesson on the board and explains to them what they are expected to do during activity exercise (15 minutes).

Presentation: The teacher presents the lesson in the following steps (60 minutes).

Step I: The teacher begins the lesson by explaining to the students what they are going to learn: the effect of temperature on system in chemical equilibrium using cooperative learning strategy where all of them will work cooperatively, and that the success of the group depends on the success of the individual member of the group.

Step II: The teacher groups the students into a cooperative learning group comprising of five to six students per group and makes sure that the groups are heterogeneous. The teacher then gives the expert group their tasks

Group Tasks:

1. Collect and distribute the materials
2. Take turn reading and highlighting the important information
3. As a group, decide what information should be highlighted
4. As a group, answer the questions
5. Each member must fill in the activity sheet
6. Return the materials and group member activity sheet

Step III: The teacher then explains to the students what they are expected to be doing from the beginning to the end of the lesson including the social skills they are expected to learn and apply them in their interaction with one another during the group work.

These skills may include using names, expert names, timing, asking questions and the rest. The teacher then gives the activity outline of the expert groups.

Activity outline for Expert Group (EGR)

A: Members of this group are to discuss the following specific areas:

1. Exothermic reaction
2. Endothermic reaction

B: Members of this group are to discuss the following specific areas:

1. Effect of increase in temperature on system in equilibrium
2. Effect of decrease in temperature on system in equilibrium

C: Members of this group are to discuss the following specific areas:

1. A named reversible reaction
2. Effect of increase in temperature on system in equilibrium of the reaction you gave
3. Effect of change in temperature on equilibrium constant

D: Members of this group are to discuss the following specific areas:

1. Meaning of a catalyst
2. Characteristics of a catalyst
3. Effect of adding catalyst a system in equilibrium

Roles of Expert Group Members:

Organizer: collection of group folder containing materials, distributes materials to group members, return materials to folders then to teacher

Reader: Reads the group task to the group

Timer: Keeps the time, makes sure everyone contributes to answer the questions

Encourager: Encourages group members, decides on the order the members will to read the task given to them

Specific procedure:

To begin the lesson, the teacher gives group name written on a card. Each individual member of the group will then be given specific task to work/study. His expert name attached to the study note of the task given to his/her will be provided to him/her. Each expert will be asked to study his/her task for some time. No student in the same group will be allowed to see the task given to his fellow group member students studying the same task from each group will then be asked to form expert groups where they will study collectively the task and record useful information on the worksheet earlier provided for the purpose of feedback to his/her main group.

Members of the expert groups will after sometimes be asked to break and go back to their main groups where each expert will explain his/her task to the remaining members of the group. Other members of the group will be encouraged to ask questions and clarifications from the experts. As the group discussion is on, members of the group were assigned to perform certain role like the time keeper, questioner, reader, reminder etc, will be doing their job.

Evaluation: The teacher evaluates the lesson by asking the students questions based on bahavioural objectives (10 minutes).

Conclusion: The teacher concludes the lesson by collecting students' worksheet papers for assessment (5 minutes).

LESSON PLAN FOR THE EXPERIMENTAL GROUP

Lesson Six

Topic: Ionic equilibria

Level: SS II

Length of the class period: 90 minutes

Model of Teaching: Cooperative learning (Jigsaw) model

Behavioural Objectives:

By the end of the lesson, the students should be able to:

1. Define acid and bases
2. Explain acid-base equilibrium
3. Solubility product of a soluble salt
4. Enumerate the equilibrium constant of a hydrolysis of salt and water

Instructional materials: A chart showing of some strong and weak acids**,** worksheets for all students, Role cards and social names of groups, copy of study notes to all expert groups;

1. Acid and bases and their classes
2. Acid-base equilibrium
3. Solubility product of a soluble salt
4. The equilibrium constant of a hydrolysis of salt and water

Previous Knowledge: The students have been taught the meaning of acids and bases

Introduction: The teacher introduces the lesson by asking students to define strong acids and give examples, writes the new topic of the lesson on the board and explains to them what they are expected to do during activity exercise (15 minutes).

Presentation: The teacher presents the lesson in the following steps (60 minutes).

Step I: The teacher begins the lesson by explaining to the students that they are going to study the meaning of ionic equilibria using cooperative learning strategy where all of them will work cooperatively, and that the success of the group depends on the success of the individual member of the group.

Step II: The teacher then groups the students into a cooperative learning group comprising of five to six students per group and makes sure that the groups are heterogeneous. The teacher mentions the group tasks of the expert groups.

Group Tasks:

1. Collect and distribute the materials
2. Take turn reading and highlighting the important information

3. As a group, decide what information should be highlighted
4. As a group, answer the questions
5. Each member must fill in the activity sheet
6. Return the materials and group member activity sheet

Step III: The teacher explains to the students what are expected to be doing from the beginning to the end of the lesson including the social skills they are expected to learn and apply in their interaction with one another during the group work. These skills may include using names, expert names, timing, asking questions and the rest. The teacher then gives the expert groups their activity outline.

Activity outline for Expert Group (EGR)

A: Members of this group are to discuss the following specific areas:

1. Meaning of acid and bases
2. Classes of acids and bases

B: Members of this group are to discuss the following specific areas:

1. Dissociation of acid and bases in water
2. Acid – base equilibria

C: Members of this group are to discuss the following specific areas:

1. Meaning of solubility product
2. Solubility product of a soluble salt

D: Members of this group are to discuss the following specific areas:

1. Hydrolysis reaction
2. Equilibrium constant of a hydrolysis of salt and water

Roles of Expert Group Members:

Organizer: collection of group folder containing materials, distributes materials to group members, returns materials to folders then to teacher

Reader: Reads the group task to the group

Timer: Keeps the time, makes sure everyone contributes to answer the questions

Encourager: Encourages group members, decides on the order the members will read the task given to them

Specific procedure:

To begin the lesson, the teacher gives group name written on a card. Each individual member of the group will then be given specific task to work/study. His expert name attached to the study note of the task given to his/her will be provided to him/her. Each expert will be asked to study his/her task for some time. No student in the same group will be allowed to see the task given to his fellow group member students studying the same task from each group will then be asked to form expert groups where they will study collectively the task and record useful information on the worksheet earlier provided for the purpose of feedback to his/her main group.

Members of the expert groups will after sometimes be asked to break and go back to their main groups where each expert will explain his/her task to the remaining members of the group. Other members of the group will be encouraged to ask questions and clarifications from the experts. As the group discussion is on, members of the group were assigned to perform certain role like the time keeper, questioner, reader, reminder etc, will be doing their job.

Evaluation: The teacher evaluates the lesson by asking the students questions based on bahavioural objectives (10 minutes).

Conclusion: The teacher concludes the lesson by collecting students' worksheet papers for assessment (5 minutes).

APPENDIX: IV

LESSON PLAN FOR THE CONTROL GROUP

LESSON ONE

Topic: Introduction to Equilibrium

Behavioural Objectives: By the end of the lesson, students should be able to:

1. Define a reversible reaction.
2. Mention some natural processes that occur reversibly.
3. Define chemical equilibrium
4. Identify some characteristic properties of a system in equilibrium.
5. Interprete the meaning some information obtained from the system at equilibrium.

Materials/Teaching aid: Close vessel with a hot water.

Presentations of the lesson (45 minutes):

- The teacher defines a reversible reaction as a reaction that can proceed in both forward and backward under a given set of conditions. For instance, the reaction $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$ is a reversible reaction because it can proceed forward and backward direction.
- The teacher proceeds to mention some natural processes that occur naturally. These include:
  - Evaporation of water from river, sea, lakes to form vapour in the atmosphere, which later condenses back as rain.
  - Production of atmospheric oxygen is done by photosynthesis which is later consumed by plants and animals during respiration.
- The teacher also defines chemical equilibrium as a system in a reversible reaction where the rates of forward and backward reactions are equal. Equilibrium is always dynamics not static.
- The teacher states the characteristic properties of equilibrium as follows:
  - The equilibrium is always dynamic
  - The properties of the reaction are always constant
  - The rate of the forward and back word reaction are equal
  - A system at equilibrium will resist a charge

Looking at the equation below:

$N_2\ (g) + 3H_2\ (g) \rightleftharpoons 2NH_3\ (g) \quad \Delta H = -\ 92.0KJ$

The following information can be obtained from a system at equilibrium:

- The two opposing system are occurring at the same time and at equilibrium.
- The amounts in moles of the reactants and products at equilibrium are proportional to the stoichiometry in the balanced equation.
- The forward reaction is exothermic (ΔH = - ve), hence the backward is endothermic.

Evaluation (10 minutes):

1 List any two (2) natural processes that occur reversibly.

2 What is equilibrium?

3 Indicate whether the forward or backward reaction in the equation

$A + B \rightleftharpoons C + D \Delta H = +ve$ is exothermic or endothermic reaction.

Summary/conclusion (5 minutes):

The teacher summarises the main points of lesson:

- A reaction that can proceed both forward and backward direction is called a reversible reaction.
- The rates of forward and backward reaction are equal in equilibrium reaction.

LESSON TWO

Topic: Law of mass action and equilibrium constant

Behavioural objectives: By the end of the lesson students should be able to:

1. State the law of mass action.
2. Write the equation for equilibrium constant.
3. Express the equilibrium constant of some reactions.
4. State the relationship between equilibrium constant and free energy in equation.

Presentation of the lesson (45 minutes):

- The teacher states the law of mass action that, at the constant temperature, the rate of a reaction is proportional to the active masses of the reactants and products.
- The teacher proceeds to derive the equilibrium constant using the equation below

$mA + nB \rightleftharpoons pC + qD$

Let the rate of forward reaction be r_1, then

$r_1 \alpha\ [A]^m\ [B]^n$, hence $r_1 = k_1[A]^m\ [B]^n$

Let the rate of backward reaction be r_2, then

$r_2 \alpha\ [C]^p\ [D]^q$, hence $r_2 = k_2[C]^p\ [D]^q$

At equilibrium, $r_1 = r_2$ i.e.

$k_1\ [A]^m\ [B]^n = k_2[C]^p\ [D]^q$

Hence $\frac{K1}{K2} = \frac{[C]p\ [D]q}{[A]m\ [B]m}$

$$K_c = \frac{[C]^p\,[D]^q}{[A]^m\,[B]^n}$$

Where K_c = Equilibrium constant

$[A]^m$= Active mass of A

$[B]^n$= Active mass of B

$[C]^p$= Active mass of C

$[D]^q$= Active mass of D

- The teacher says that, the quantitative relationship between the free energy charge at any temperatures, ΔG, the free energy charge at standard states, ΔG^o and equilibrium constant, K at a given temperature T is given by the expression

$\Delta G = \Delta G^o + 2.303RTlogK$

Where R is the universal gas constant

Hence, $\Delta G^o = - 2.303RTlog_{10}{}^k$

Evaluation (10 minutes):

Express the equilibrium constant for the reaction below:

1. $N_2 + 3H_2 \rightleftharpoons 2NH_3$
2. $H_2 + I_2 \rightleftharpoons 2HI$

Summary/Conclusion (5 minutes)

The teacher corrects students' mistakes during evaluation.

LESSON THREE

Topic: Le - Chatelier's Principle

Behavioural objectives: By the end of the lesson, students should be able to:

1. State Le - Chatelier's Principles.
2. List factors that can affect the system in equilibrium.
3. Explain the effect of change in concentration of reactants or products.

Use the equation of equilibrium constant to explain effect of change in concentration.

Presentation of the lesson (45 minutes):

- The teacher states Le - Chatelier's princple that, when a system in equilibrium is subjected to a change by an external factor (such as temperature, concentration and pressure), the equilibrium shifts in order to oppose the change and restore back the equilibrium.

Factors that affect system in equilibrium are as follows:

- Changes in concentration of reactants or products.
- Changes in temperature of the system.
- Changes in pressure of the system.
- Addition of catalyst

- The teacher explains that, when the concentration of the reactants in increased, the equilibrium will shift in favour of the product thereby forming more of the product and restore back the equilibrium. For instance, in the equation bellow:

$Fe^{3+}_{(aq)}$ + $3SCN^{-}_{(aq)} \rightleftharpoons$ $Fe(SCN)_{3(aq)}$

(yellow) (colourless) (Deep red)

When potassium thiocyanate, KSCN is added, the concentration of SCN increases which favours forward reaction, and hence intensity of the deep red colour i.e. formation of more product.

- Considering an equilibrium system such as A $\rightleftharpoons$ B +C

The equilibrium constant K_c is

$$K_c = \frac{[B]\,[C]}{[A]}$$

If [A] is increased at equilibrium, K_c decreases at the given temperature. For K_c to remain constant [B] or [C] must increase i.e. the forward reaction is favoured by increasing [A].

Evaluation (10 minutes):

- Explain the effect of concentration when H_2 is added in the equation below:
- $H_2 + I_2 \rightleftharpoons 2HI$
- Write the equilibrium constant for the reaction $N_2 + 3H_2 \rightleftharpoons NH_3$

Using the expression, explain the effect of increasing $[NH_3]$to the reaction

Summary/Conclusion (5 minutes)

The teacher summarizes the lesson by correcting students mistakes committed during the process of evaluation.

LESSON FOUR

Topic: Effect of changes in pressure of a system.

Behavioural objectives: By the end of the lesson, students should be able to:

1. Define pressure
2. Explain the effect of pressure on system in equilibrium.
3. Use an equation and explain the effect of change in pressure on the system.

Presentation of the lesson (45 minutes):

- The teacher defines pressure as the force acting against a particular area or substance.
- The teacher explains that pressure only affects gaseous reactants or products but has no effect on solid or liquid in the system in equilibrium.
- Generally, an increase in pressures on a system in equilibrium shifts the equilibrium position in favour of the side with smaller volume (or amount) of gas. Conversely, a decrease in pressure shifts the equilibrium position in favour of the side with larger volume of gas.
- Considering the production of ammonia by Haber process

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons NH_{3(g)}$

In the above reaction, a decrease in volume accompanies the forward reaction, which leads to the formation of ammonia, white and increase in volume accompanies the backward reaction, which is the decomposition of ammonia.

Evaluation (10 minutes):

Explain how the equilibrium position is affected by a change in pressure in the following reactions

$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

Summary/conclusion (5 minutes)

- The teacher summarizes the major points of the lesson that, the effect of pressure on system in equilibrium can only be possible when the volumes or amount of reactants and products are not equal.
- Increase in pressure favours smaller volume while decrease in pressure favours larger volume.

LESSON FIVE

Topic: Effect of changes in temperature on the system and effect of catalyst

Behavioural objectives: By the end of the lesson, students should be able:

1. Identify in reversible, an endothermic or exothermic reaction.
2. Explain effect of change in temperature on system in equilibrium.
3. Describe the effect of change in temperatures of a system on given equation.
4. Explain the effect of catalyst on a system of equation.

Presentation of the lesson (45 minutes):

- The teacher tells the students that, from the chemical equation below, the forward reaction is an exothermic reaction (ΔH = - ve) while the backward reaction is an endothermic reaction (ΔH = +ve).

$H_{2(g)} + Cl_{2(g)} \rightleftharpoons 2HCl_{(g)}$; $\Delta H = - 774kJ$

- The teacher continues to say that, an increase in temperature on a system at equilibrium causes equilibrium to shift in favour of an endothermic reaction while a decrease in temperature favour an exothermic reaction in order to restore equilibrium.
- Considering the chemical equation above, an increase in temperature on the system causes the equilibrium to shift in favour of the backward reaction (endothermic reaction) thereby decomposing HCl, while a decrease in temperature causes the equilibrium to shift in favour of the forward reaction (exothermic reaction) thereby forming more of HCl.
- The presence of a catalyst in a reversible reaction has no effect on the equilibrium position (or equilibrium constant) but lowers the activation energy of both forward and backward reactions and shortens the time for attainment of equilibrium.

Evaluation (10 minutes):

Consider the following equation:

$H_2S + M^{2+} \rightleftharpoons MS_{(s)} + 2H^+_{(aq)}$ $\Delta H = - XKJ$

State and explain the effect of each of the following on the equilibrium position.

a. Increase in temperature
b. Addition of solution of $M(NO_3)_2$
c. Addition of acidified $KMnO_{4(aq)}$

Summary/conclusion (5 minutes):

- Generally increase in temperature on system in equilibrium favours endothermic reaction while decrease in temperature favours exothermic reaction.
- Catalyst has no effect on the system in equilibrium but makes the equilibrium to be reached faster.

LESSON SIX

Topic: Ionic equilibrium

Behavioural objectives: By the end of the lesson, the student should be able to:

1. Explain acid-bas equilibrium
2. Describe solubility equilibrium of a soluble salt
3. Enumerate the equilibrium constant of a hydrolysis of salt and water

Presentation of the lesson (45 minutes):

- In aqueous solution, a strong acid will dissociate to give a weak conjugate base, white as weak acid will dissociate to give a strong conjugate base. Similarly a strong base will dissociate to give a weak conjugate acid, while a weak base will dissociate to give a strong conjugate acid.
- When a weak acid, HA ionizes in water; the following equilibrium is set up:

$HA + H_2O_{(1)} \rightleftharpoons H_3O_{(aq)} + A^-_{(aq)}$

$K_a = \frac{[H_3O^+][A^-]}{[HA]}$

K_a= dissociation constant of the acid; the higher the value of K_a the stronger the acid.

- In a saturated solution of a sparingly soluble salt and equilibrium exists between the ions and the undissolved salt when the rate at which the ions are precipitated from the saturated solution:

Undissolved salt $\rightleftharpoons$ Ions in solution

e.g. $AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$

$K_c = \frac{[Ag^+_{(aq)}][Cl^-_{(aq)}]}{[AgCl_{(s)}]}$

But $[AgCl_{(s)}] = 1$

$K_c = \frac{[Ag^+_{(aq)}][Cl^-_{(aq)}]}{1}$

$K_c = [Ag^+_{(aq)}]\,[Cl^-_{(aq)}] = Ksp$

The new constant, Ksp is called the solubility product.

- In cation hydrolysis, the resulting solution will be acidic, white in anion hydrolysis, the resulting solution will be alkaline. For instance, for the hydrolysis of an anion of weak acid.

$HA + H_2O \rightleftharpoons H_3O^+ + A^-$

$Kh = \frac{[H_3O^+][A^-]}{[HA]}$

K_h = hydrolysis constant

Evaluation (10 minutes):

- The [OH^-] of water solution is 1.00×10^{-4}moldm^{-3}. What is the [H^+]
- Write the expression of the solubility product of (a) PbCl (b) $Ca_3(PO_4)_2$

Summary/Conclusion (5 minutes)

The teacher stresses that, the relationship between Ka, K_h and K_w is written as:

$K_w = K_a \times K_h$

Where K_w = hydrolysis constant of a weak acid

K_h = hydrolysis constant

K_a = dissociation of an acid

APPENDIX V

COOPERATIVE INSTRUCTIONAL PACKAGE (CIP)

Number of activities

Topic	Activity
Reversible reactions	1a
Attaining equilibrium position from any starting point	1b
Law of mass action/equilibrium constant	2
Describing the effect of change in concentration of reaction and product on the equilibrium	3
Effect of change in pressure on the system in equilibrium	4
Describing the effect of change in temperature	5
Determining the relative strength of some acids and bases	6

ACTIVITIES FOR COOPERATIVE INSTRUCTIONAL PACKAGE (CIP)

Activity Ia: Reversible Reactions

Materials: Bunsen burner, tripod stand, calcium trioxocarbonate (iv), a flat bottom flask with a cover.

Instructions: You are provided with the above materials, perform the following.

- Take about 5g of $CaCo_3$crystals and transfer into the flask given to you.
- Cover the flask.
- Apply heat gently to the closed flask
- What did you observe at the starting point ……………………………………………...……………………………………
  ………………………………………………………………………………………
  ………………………………………………………………………………………
- Describe the changes that happened to system after supplying enough heat………………………………………………………………………………
  ………………………………………………………………………………………
  ………………………………………………………………………………………

  In your own words, state the reason why the container was covered ………………………………………………………………………………………
  ………………………………………………………………………………………
  ………………………………………………………………………………………

Activity Ib: Attaining equilibrium from any starting point.

Materials: Test-tube, potassium iodide, iodine crystals and trichloromethane.

From the materials given to you above, perform the activities below and report your observations (colour changes).

System A: Dissolve a crystal of iodine in 10cm^3 of trichloromethane. To it, add 10cm^3 of 1M potassium iodide.

Observation:

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………

System B: Dissolve a crystal of iodine in 10cm^3 of 1M aqueous potassium iodide. To it, add 10cm^3 of tricholomethane.

Observation:

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

Conclusion: Equilibrium position

Compare system A and system B on attaining equilibrium ………………………………..……………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

Activity II: Equilibrium constant

- Using the equation below

$N_{2(g)} + H_{(2)g} \rightleftharpoons NH_{3(g)}$

- What does the arrow signifies …………………………………………………

  …………………………………………………………………………………

  …………………………………………………………………………………

- Write the balanced equation for the reaction……………………………………

  …………………………………………………………………………………

  ………………………………………………………………………………...

- From the balanced equation above express the equilibrium constant of the reaction………………………………………………………………………

  ………………………………………………………………………………

- In each of the questions given below, work out the equilibrium constant for the reaction.

Question 1: An equilibrium mixture is analyzed and found to contain 0.62moldm^{-3} NH_3. What is the equilibrium constant, Kc for the reaction?

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………

Question 2: An equilibrium mixture is analysed and found to contain 0.89moldm^{-3} N_2, 0.76moldm^{-3}H_2, and 0.36moldm^{-3} NH_3. What is the equilibrium constant, Kc for the reaction?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………

- From the values of Kc calculated, indicate whether the values are same or different ……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
- State your reasons ……………………………………………………………………
……………………………………………………………………………………
…………………………………………………………………………………….

A**ctivity III:** Investigating the effect of change in concentration of reactant or products on equilibrium

Materials: Four test tubes, iron (iii) trioxonitrate (v), potassiumthiocyanate.

Method: Weigh out 13g of iron (iii) trioxonitrate (v) and 8g of potassiumthiocyanate. Dissolve each in 50cm^3 of water. Add equal volumes of these two solutions to obtain the blood-red iron (iii) thiocyanate solution to teach. To test-tube A add a few crystals of potassium thiocyanate; test tube B, a few crystals of iron (iii) trioxonitrate (v), and test tube C, a few drops of silver trioxonitrate (v) solution while test tube D should remain as it is i.e. without adding anything to it. Use test tube D to compare the changes in colour of solutions A, B and C.

Record any colour change in the table below:

Test tube	Intensity of red colour	Conc. of iron (iii) thiocyanateios	Effect on equilibrium position i.e. right or left
A			
B			
C			

Using Le-Chatelier's principle, explain the effect of change in concentration of the thiocyanate ions and iron (iii) ions …………………………………………………………

…………………………………………………………………………………………

Conclusion: On shift of the equilibrium position in your own words, indicate the effect of removing or addition any one of the reactant or products to the equilibrium position …………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………

Activity IV: Effect of change in pressure on equilibrium of reaction mixture.

Materials: Syringe, nitrogen (iv) oxide and dinitrogen (iv) oxide.

Perform the following activities carefully.

- Collect about $80cm^3$ of gas in a syringe and note its colour at normal pressure.
- To increase the pressure of the system, push the plunger down quickly to compress the gas to $30cm^3$ and note the colour change immediately.
- After a few seconds, note its colour again then withdraw the plunger to the $80cm^3$ mark and observe the colour changes.

Record your result as follows:

a. …………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

b. …………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

c. …………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

Conclusion: From the result obtained above, indicate the effect of change in pressure on equilibrium position. ……………………………………………………………………….
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Activity V: Determining the effect of temperature change on equilibrium

Materials: Syringe, beakers, stand, bursen burner, ice, and lead (ii) trioxonitrate (v).

Instructions: You are provided with the above materials, perform the following activities and record your observations and results.

- Place some lead (ii) trioxonitrate (v) crystals in a test tube and heat strongly. When reddish-brown fumes start to evolve, connect a gas syringe with rubber tubing to the test tube. Slowly withdraw the plunger to collect about $50cm^3$ of the gas. Allow the gas in the syringe to cool down to room temperature. Note its colour.

- Set up two beakers one containing ice-water at 0^oC and another containing hot water at 100^oC. Immerse the syringe containing the gas collected in (a) into the ice-water for a few minutes. Note the rapid change in colour. Next, plunge the syringe into the hot water and observe what happens.

Results:

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Conclusion: In your words, write a conclusion from the above activities to describe the effect of change in temperature. ……………………………………………………

Activity VI: Determining the relative strength of acid and bases.

Set up the electrical circuit as show in fig 3.7:

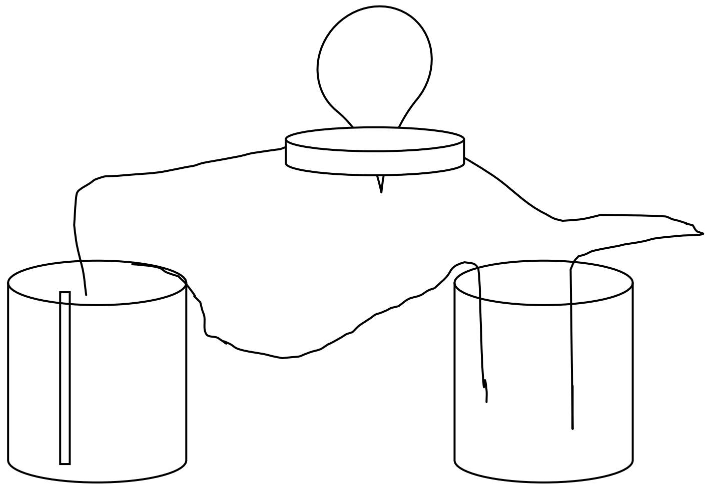


Figure 3.7: Electric circuit

Pour separately into a beaker $20cm^3$ of these acid H_2SO_4, HNO_3, CH_3COOH, H_2CO_3 and HCl.

- Compare the intensity of the light bulb.
- Use these result to describe your acids as strong or weak and tabulate your result below:

Table 3.5 a: Determining strength acids

Substance	Light bulb	Description of substance
H_2SO_4		
HNO_3		
CH_3COOH		
H_2CO_3		
HCl		

Repeat the experiment with the following bases NaOH, KOH, NH_4OH and methylamine. Record your results below.

Table: 3.5 b: Determining strength bases

Substance	Light bulb	Description of substance
NaoH		
KOH		
CH_3NH_2		
NH_4OH		

- How did you identify the strong acids and bases from weak acids and explain.
- The strength of acids/bases can be determined by using…………………………
- Acids that are completely dissociated in water are called strong while those that are partially dissociated in water are called ……………………………………
- Also strong bases are complete dissociated in water while ………………….. are partially dissociated in water.

APPENDIX VI

STUDY MATERIAL

Reversible Reactions

Reversible reactions: are reactions that can be made to proceed both forward and backward directions, under a given set of conditions.

Examples of reversible processes that occur naturally:

- Evaporation of water from rivers, lakes a from sea to form water vapour which later condenses to form cloud that eventually falls as rain.
- Production of oxygen by photosynthesis which is eventually consumed by plants and animals.
- Boiling of water in a closed container produces steam on top of the container which after condensation turns back as water which after condensation turns back as water.

A reversible reaction occurs in a closed vessel.

Chemical Equilibrium

Equilibrium is defined as a state in a reversible reaction in which the rates of forward and backward reactions are equal.

- An equilibrium is always dynamic i.e. equilibrium can be achieved from either direction of reactants or products.
- The rates of forward and backward reactions are equal.
- Catalyst only quickens the rate at which equilibrium is achieved
- A system at equilibrium will resist change.

Information Obtainable from an Equilibrium Equation

Consider a typical reversible reaction;

$N2 + 3H2(g) \rightleftharpoons 2NH_3(g)$

The following information can be obtained

- The two opposing reactions are occurring at the same time – as indicated by the double arrows
- The two opposing reactions are at equilibrium
- The amounts in moles, of reactants and products at equilibrium are proportional to the stoichiometry in the balanced equation
- The forward reaction is exothermic ($\Delta H = -$ ve); hence, the backward reaction will be endothermic reaction ($\Delta H = +$ ve)

Law of mass action/Equilibrium constant

The law states that, the rate at which a reaction proceeds is directly proportional to the concentration of the active species in the system.

Consider a reversible reaction:

$mA + nB \rightleftharpoons pC + qD$

The rate of forward reaction, r_f is:

$r_f \alpha [A]^m [B]^n$ or $r_f = K_f [A]^m [B]^n$

Similarly, the rate of backward reaction, r_b, is:

$r_b \alpha [C]^p [D]^q$ or $r_b = K_b [C]^p [D]^q$

Where K_f and K_b are the rate constants for the forward and backward reactons respectively.

At equilibrium, the rate of forward and backward reactions, is equal i.e. $r_f = r_b$

Hence, $k_f [A]^m [B]^n = k_b [C]^p [D]^q$

On rearrenging, the equation becomes;

$\frac{K_f}{K_b} = \frac{[A]^m [B]^n}{[C]^p [D]^q}$ or

$K_c = \frac{[A]^m [B]^n}{[C]^p [D]^q}$ or $\frac{[products]}{[reactants]}$

Where Kc = equilibrium constant

$[A]^m$ = active mass of A

$[B]^n$ = " " " B

$[C]^p$ = " " " C

$[D]^q$ = " " " D

The equation below gives the relationship between equation constant, Kc and free energy change ΔG at standard states

$\Delta G^0 = -2.303RT\log_{10}K$

Where ΔG^0 = Standard free energy

R = Rate constant

T = Temperature in Kelvin

K = Equilibrium constant

Exercise

Express the equilibrium constant for the reactions below;

1. $N2 + 3H2(g) \rightleftharpoons 2NH_3(g)$
2. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

Le- Chatelier's Principle

The principle states that, when a system in equilibrium is subjected to a change by an external factor, the equilibrium shifts in order to oppose the effect of the change and restore back the equilibrium.

Factors affecting system in equilibrium

Factors that affect system in equilibrium are:

1. Changes in concentration of reactants and products
2. Changes in pressure of the system
3. Changes in temperature of the system
4. Addition of catalyst

Effect of change in concentration on system in equilibrium

In a reversible reaction, when the concentration of reactant is increased, the equilibrium will shift in favour of the product. Thereby forming more of the product and restore back the equilibrium (Le-chatelier's principle).

For instance, in the equation below;

$Fe^{3+}(aq) \quad + \quad 3SCN^{-}(aq) \rightleftharpoons Fe(SCN)_3(aq)$

Yellow (colourless) (Deep red)

When KSCN (Potassium cynate) is added, the concentration of SCN increases which favours forward reaction, and hence, intensity of the deep red colour i.e. formation of more produce. Also the concentration of SCN decreases, the opposite i.e. backward reaction will be favoured.

Considering an equilibrium system such as

$A \rightleftharpoons B + C$

The equilibrium constant, K_C is

$$K_c = \frac{[B]\,[C]}{[A]}$$

If [A] is increased at equilibrium Kc decreases at given temperature. For Kc remain constant, [B] or [C] must increase i.e. the forward reaction is favoured by increasing [A].

Exercise

Explain the effect of concentration when H_2 is added to a system in the equation below.

$H_2 + I_2 \rightleftharpoons 2HI$

Effect of pressure change on system in equilibrium

To understand the effect of change in pressure on equilibrium, we say that, pressure only affects gaseous reactants or products but has not effect on solid or liquid in the system in equilibrium. Generally, an increase in pressure on a system in equilibrium shifts the equilibrium position in favour of the side with smaller volume (amount) of gas. Conversely, a decrease in pressure shifts the equilibrium position in favour of the side with larger volume of gas. For instance,

$$N_{2(g)} \quad + \quad 3H_{2(g)} \quad \rightleftharpoons \quad 2NH_{3(g)}$$

1Vol. 3Vol. 2Vol.

In the above equation; a decrease in pressure favours the forward reaction (formation of among) while increase in pressure favours the backward reaction (decomposition of ammonia).

Exercise:

Explain how the equation position can be affected by a change in pressure in the following reaction:

$$N_2O_{4\,(g)} \rightleftharpoons 2NO_{2\,(g)}$$

Effect of change in temperature on system in equilibrium

The effect of temperature on system at equilibrium can be understood by recognizing that, if forward reaction is exothermic then the backward reaction will be endothermic. An increase in temperature on system at equilibrium favours endothermic reaction while a decrease in temperature on system at equilibrium favours exothermic reaction in order to restore back equilibrium. Considering the chemical equation below:

$$H_{2(g)} + Cl_{2(g)} \rightleftharpoons 2HCl_{(g)} \quad \Delta H = -774KJ$$

An increase in temperature on the system causes the equilibrium to shift in favour of the backward reaction which is endothermic i.e. decomposition of HCl while a decrease in temperature causes the equilibrium to shift in favour of the forward reaction which is an exothermic reaction i.e. forming more of the product, HCl.

Effect of catalyst on system in equilibrium

A catalyst is substance that alters the rate of a chemical reaction but remains chemically unchanged at the end of the reaction. The presence of a catalyst in a reversible reaction has no effect on system in equilibrium position or equilibrium constant but lowers the activation energy of both forward and backward reactions which shorten the time.

Consider the following equation;

$H_2S + M^{2+} \rightleftharpoons MS_{(s)} + 2H^+$ $\Delta H = -XKJ$

State and explain the effect of each of the following on equilibrium position.

a. Increase in temperature
b. Addition of solution of $M(NO_3)_2$
c. Addition of acidified $KMnO_{4(aq)}$

Ionic Equilibria

In aqueous solution, a strong acid will dissociate to give a weak conjugate base, while a weak acid will dissociate to give a strong conjugate base. Similarly a strong base will dissociate to give a weak conjugate acid, while a weak base will dissociate to give a strong conjugate acid. When a weak acids, HA Ionizes in water, the following equilibrium is set up.

$$HA_{(aq)} + H_2O \rightleftharpoons H_3O^+ + A^-_{(aq)}$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

K_a = Dissociation constant of the acid; the higher the value of K_a the stronger the acid.

In a saturated solution of a sparingly soluble salt, an equilibrium exists between ion and the undissolved salt when the rate at which the ions are precipitated from the saturated solution;

Undissolved salt⇌Ions in solution

e.g. $AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$

$$Kc = \frac{[Ag^+_{(aq)}][Cl^-_{(aq)}]}{[AgCl_{(s)}]}$$

But $[Ag\,Cl_{(s)}] = 1$

$K_c = [Ag^+_{(aq)}]\,[Cl^-_{(aq)}] = K_{sp}$

The New constant, K_{sp} is called the solubility product.

In cation hydrolysis, the resulting solution will be acidic, while in anion hydrolysis, the resulting solution will be alkaline. For instance, in the hydrolysis of an anion of weak acid;

$$HA + H_2O \rightleftharpoons H_30^+ + A^-$$

$$Kh = \frac{[H_3O^+][A^-]}{[HA]}$$

Where K_h = hydrolysis constant

Exercise

- The [OH^-] of water solution is 1.00 x 10^{-4} $moldm^{-3}$.

What is the [H^+]

- Write the expression for the solubility product of; (a). $Pbcl_2$ (b). $Ca_3(PO_4)$

APPENDIX VII

ITEM ANALYSIS FOR INSTRUMENT CPT

Item no	Upper (N=10)	Lower(N=10)	Difficulty level (U+L/N)	Discrimination Index (U-L/0.5N)	Percentage
1	0	0	0.00	0.00	0.0
2	1	0	0.03	0.07	3.3
3	3	2	0.17	0.07	16.7
4	1	0	0.03	0.07	3.3
5	3	1	0.13	0.13	13.3
6	3	3	0.20	0.00	20.0
7	2	0	0.07	0.13	6.7
8	1	0	0.03	0.07	3.3
9	3	1	0.13	0.13	13.3
10	4	2	0.20	0.13	20.0
11	2	2	0.13	0.00	13.3
12	2	0	0.07	0.13	6.7
13	5	2	0.23	0.20	23.3
14	4	2	0.20	0.13	20.0
15	2	2	0.13	0.00	13.3
16	5	5	0.33	0.00	33.3
17	2	0	0.07	0.13	6.7
18	5	4	0.30	0.07	30.0
19	3	2	0.17	0.07	16.7
20	3	1	0.13	0.13	13.3
21	3	1	0.13	0.13	13.3
22	1	0	0.03	0.07	3.3
23	7	2	0.30	0.33	30.0
24	2	1	0.10	0.07	10.0
25	0	0	0.00	0.00	0.0
26	4	1	0.17	0.20	16.7
27	0	0	0.00	0.00	0.0
28	2	1	0.10	0.07	10.0
29	0	0	0.00	0.00	0.0
30	0	0	0.00	0.00	0.0
31	1	0	0.03	0.07	3.3
32	7	4	0.37	0.20	36.7
33	8	6	0.47	0.13	46.7
34	3	2	0.17	0.07	16.7
35	6	4	0.33	0.13	33.3
36	8	7	0.50	0.07	50.0
37	6	6	0.40	0.00	40.0
38	7	0	0.23	0.47	23.3
39	4	2	0.20	0.13	20.0
40	5	5	0.33	0.00	33.3

APPENDIX VIII

ITEM ANALYSIS FOR INSTRUMENT TOSPS

Item no	Upper (N=10)	Lower(N=10)	Difficulty level (U+L/N)	Discrimination Index (U-L/0.5N)	Percentage
1	1	1	0.07	0.00	6.7
2	2	6	0.27	0.27	26.7
3	3	0	0.10	0.20	10.0
4	2	2	0.13	0.00	13.3
5	1	3	0.13	0.13	13.3
6	3	1	0.13	0.13	13.3
7	3	1	0.13	0.13	13.3
8	3	2	0.17	0.07	16.7
9	5	3	0.27	0.13	26.7
10	4	2	0.20	0.13	20.0
11	5	1	0.20	0.27	20.0
12	6	4	0.33	0.13	33.3
13	2	1	0.10	0.07	10.0
14	3	7	0.33	0.27	33.3
15	3	7	0.33	0.27	33.3
16	5	4	0.30	0.07	30.0
17	2	1	0.10	0.07	10.0
18	1	2	0.10	0.07	10.0
19	2	2	0.13	0.00	13.3
20	3	3	0.20	0.00	20.0
21	1	3	0.13	0.13	13.3
22	2	1	0.10	0.07	10.0
23	2	2	0.13	0.00	13.3
24	4	3	0.23	0.07	23.3
25	8	4	0.40	0.27	40.0